The Role of Big Data Technologies in Geographically Distributed Medical Organizations' IT Service Architecture

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Abstract The paper presents an analysis of how big data technologies can be applied to the business activities of geographically distributed medical organizations. Characteristics of geographically distributed medical organizations are analyzed in the context of information requirements and opportunities of big data matching these requirements. A case study is presented, describing a Russian geographically distributed organization's functional structure and enterprise architecture model presenting, how IT applications and big data technologies interact when realizing analytics IT services.

Keywords Medical organizations · Geographically distributed medical organizations · IT service architecture · Big data in health care

1 Introduction

The introduction of digital technologies into the activities of modern organizations is an urgent issue for most areas of activity. The field of medicine and health care is no exception—the evolving concepts of value-based medicine, personalized and predictive medicine, as well as end-to-end digital technologies open up great opportunities for the complex digitalization of medical institutions. The implementation of projects within the framework of the state programs "Healthcare Development," "Information Society," "Digital Economy of the Russian Federation" is aimed, inter alia, at the formation of a single digital space in the field of medicine and health care. Since 2011, a program has been implemented to create a Unified State Information System in the Healthcare Sector, designed to unite the existing state information systems in the healthcare sector—information systems of medical institutions, Federal and territorial compulsory medical insurance funds, health care of the constituent entities of the Russian Federation, pharmaceutical organizations. At the same time, the issue of integrating medical and economic data within the framework of a single

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information space is relevant not only for the state but also for commercial medical institutions interacting, in addition to the above-mentioned healthcare entities, with medical insurance funds.

Over the past ten years, the number of medical information systems developed on the Russian market has approached a hundred, projects for the implementation of such systems have been successfully completed in many medical organizations, however, the challenges of digital transformation and the need to create a unified information space in the field of medicine and health care form new requirements for information and technological support of both the processes of providing medical care and the processes of managing medical organizations. At the same time, the issue of the development of the management system and its information technology support becomes especially relevant for geographically distributed organizations due to the need to ensure the quality and compatibility of data from various sources for the purpose of their comprehensive analysis, the formation of corporate reporting and compliance with legal requirements.

Reforming the activities of medical organizations, caused by the need to introduce end-to-end digital technologies, including technologies for collecting, storing, and processing big data, poses an urgent task to develop architectural models for the activities of geographically distributed organizations, taking into account the possibilities of digital technologies.

2 Materials and Methods

The object of the research is represented by geographically distributed medical organizations, situated in Russian Federation. The first part of the Results paragraph describes types and forms of medical organizations in Russian Federation according to the type of ownership and geographical factor.

The second part of the Results paragraph represents the review of the possibilities of applying Big Data technologies in medical organizations focusing on those topical for geographically distributed organizations, which basically means there are several clinics located in different regions. Here, the method of analysis of literary sources is used, including scientific articles, monographs, reports of consulting and research companies.

The last part of the Results paragraph represents the Case of a Russian geographically distributed medical organization, where IT service architecture, based on Big Data opportunities, is modeled. The main research methods used in this part of research are:

- The enterprise architecture (EA) approach [1], which allows modeling the business, information and technology domains of an enterprise in order to analyze the interdependencies of the domain's object and to realize organization development projects based on the results of such analysis. The TOGAF EA framework and ArchiMate EA modeling language represent the methodological basis EA approach.

- The method of modeling IT service architecture is presented in Dubgorn [2]. This method involves the implementation of the following steps:

  – Formation of a functional model of the organization.
  – Determine the needs of business functions in IT services.
  – Analysis of the capabilities of information systems and digital technologies.
  – Formulation of the main task of the IT service (naming the IT service).
  – Adding the identified IT service into the overall service architecture.

3 Results

3.1 Toward Geographically Distributed Medical Organizations in Russian Federation

All modern medical organizations in Russian Federation can be conditionally divided into two groups: localized and geographically distributed.

The term “localized” means that a given company is located in a relatively small area with uniform environmental conditions for all its divisions and with the possibility of organizing its control and management activities through unified channels [3].

The structure of complex geographically distributed organizations corresponds to the network model. The development of networks covering several medical organizations has become one of the notable trends in recent times. The economic growth of the past decade has given a powerful impetus to phenomena such as corporate network clinics and private medical networks not directly associated with corporations.

It should be noted that the phrase “network of medical clinics” refers to a group of enterprises, which, regardless of the organizational and legal form of its individual units and regardless of the details of the management system, is united by the presence of common material and technological resources. In other words, within the network, there is a fairly free, although not always strictly formalized exchange of personnel, funds, and information. Commercial networks usually have a common composition of owners, although franchise schemes have also appeared recently. In public institutions, the elements of the network structure can be presented as an option in the form of regulatory, methodological, and administrative links between organizational units. As in other industries, the network model in health care can reduce administrative costs, form service delivery standards, gain economies of scale in procurement, etc. [4].

Networks of medical organizations are usually represented by the following organizational models:

- A large (multidisciplinary) healthcare facility located in several buildings, possibly geographically distant from each other.
- A network of branches with separate legal entities.
- Close cooperation of several "friendly" healthcare facilities, roughly equivalent in capacity, but possibly with different specializations.

Let us list some features of each of the above cases.

Large (multidisciplinary) healthcare facility at geographically close or remote sites.

- One legal entity.
- The structure includes several components of the same type, such as Hospital, Paraclinic, Polyclinic (it should be noted that they are not always explicitly present in the organizational structure of medical facilities).
- The collection of statistical data on various aspects of activities is carried out both in the context of the building (territory, site) and throughout the healthcare facility as a whole.
- Unified database of patients, electronic medical records. It is possible to maintain several paper outpatient records for one patient (in different buildings), but for management, it is important to combine the history of visits/cases of patient care, the transition to a single electronic medical record.
- Transfer of patients from departments of one building to departments of another is possible. It is considered a hospital transfer. But more often the movement of patients occurs within the same building/territory.
- A unified register of services is being formed. Financial statements are generated from the organization as a whole.
- Material supply is carried out through the central warehouse (according to the accessories—pharmacy, medical equipment, catering, etc.).

A number of "friendly" healthcare facilities

Such forms of cooperation are often found in the work of departmental institutions that have not only a contingent of the same affiliation, but also a certain degree of freedom in such areas of mutual cooperation as the exchange of information, the direction of patient flows, etc. An example is departmental health facilities with differing sets of patient care options. For example, one has the capacity of an immunological laboratory, the other has tomography and angiography, and at the same time contracts are concluded for the mutual service of patients in the amount of services that are not available at this healthcare facility. Private clinics can also informally unite into similar structures to optimize their activities, provide an expanded range of services, etc.

Branch network

It is formed on the basis of/with the separation of the head institution, either multidisciplinary or specialized. Branches can be both separate legal entities and as part of the head medical institution (usually with a close territorial location).

- Branches are registered, as a rule, as separate legal entities.
- Among the individual linear, located on the periphery of the branches, there can be found both consisting of only one component (as a rule, it is a Polyclinic), and complex. The central healthcare facility is a large complex multidisciplinary medical institution (see especially above) or specialized.
- The collection of statistical data is carried out separately for each branch. At the head office, it is also necessary to analyze the aggregated statistics for the entire network. Much attention is paid to the design of patients transferred from the branches to the Center (completeness, correctness, timeliness of documentation, the quality of medical measures is assessed at all levels of the network).
- The exchange of initial data is necessary to ensure the continuity and correct continuation of treatment.
- Transfers of patients to another healthcare facility are issued with an extract and accompanied by all the necessary documentation. It is possible to provide additional data, analyze the correspondence of information in the outgoing and receiving healthcare facilities (the coincidence of diagnoses, assessment of the quality of medical care at the previous stage, etc.).
- Service registers are formed separately. The center receives summary information about the financial performance of each health facility in the network.
- Material supply is carried out through the central warehouses of each legal entity (centralized purchases are possible with transfer to the warehouses of branches) [5].

Based on the analysis [6–8] the following principles of a geographically distributed medical organization's management were considered:

Centralized control system;

Functional subordination to the relevant departments the parent company in priority over the administrative subordination to the management of the branch;

- Transparency;
- Office of Exceptions;
- Single information space;
- Standardization of process management;
- Uniform standards for the implementation of activities;
- Accounting and adaptation to local (economic, cultural, etc.) peculiarities of the branch location.

All of the above principles should be taken into account when considering the possibilities of using certain digital technologies in the activities of geographically distributed medical organizations.

3.2 Big Data Opportunities for Medical Organizations

In the field of health care, one can single out such areas of application of Big Data as solving problems of personalized medicine, forecasting epidemics, combating existing diseases, treating, and preventing diseases, improving treatment methods based on a huge statistical base [9]. The main purpose of using Big Data in health care is aimed at processing biomedical data, data analysis, visualization, and obtaining results.

Big data can be classified into three main groups:

- transactional data—data from invoices, payment orders, storage records, delivery records, orders, and expense data;
- clinical data—data collected from medical information systems, industrial equipment, real-time data from sensors and wearable technologies, medical mobile applications as well as weblogs that track user behavior on the Internet;
- social data—data coming from social services such as Facebook, Twitter, VK, and YouTube that provide insight into patient behavior and moods [10].

Presenting the results of an in-depth study of the possibilities of Big Data technology for use in the medical field, the following should be highlighted:

- carrying out comprehensive diagnostics allows solving the problems of diagnosing rare diseases, preventing epidemics;
- processing of the data collection results obtained using signals from medical gadgets. New medical devices allow collecting information about a patient and sending it to one data warehouse;
- information support for emergency assistance, which allows timely diagnosis of critical conditions, prevention of lethal effects of the environment;
- medical assistance using telemedicine technologies. This allows for remote examination, promptly prescribing the trajectory of treatment;
- introduction of comprehensive prevention, which allows for comprehensive treatment of patients receiving a range of drugs. In the event of an operation, it becomes necessary to process an array of data on the patient's life processes;
- supporting patient safety in intensive care and intensive care units using analytical systems to predict surgical risk;
- reducing costs with the help of value that drives better patient outcomes for long-term savings;
- the intelligence of electronic health records (EHR) [11].

Big data processing technologies allow you to answer 4 types of questions [12]:

- Descriptive (descriptive analytics)—"what happened?" The purpose of such an analysis is to compose an objective and maximally accurate description of the current situation, to turn huge amounts of data into accessible, understandable, and easily perceived information. Most organizations today are at this initial stage of analytics and even here are experiencing enormous difficulties due to data shortages.

- Diagnostic—"why did this happen?" The purpose of diagnostic analytics is to identify predictors of the development of the current situation. Such analytics still implies a retrospective analysis, but it still allows us to understand the reasons for certain trends, shortcomings and outline ways to improve.
- Predictive (predictive analytics)—"what happens next?" The purpose of predictive analytics is to predict the onset of certain events, to model development scenarios. Competent predictive analytics systems can predict changes in patient flows, simulate clinical scenarios and the time a patient is in a particular stage of medical care, simulate the epidemiological situation, predict morbidity, outcomes, mortality [13].
- Prescriptive (prescriptive analytics)—"what to do?" The goal is to build a trajectory of change to obtain the desired result. Prescriptive analytics is the highest level of data manipulation. It allows, based on the model, to determine what needs to be changed in order to reach the desired result, in what time frame and with what resources. As you move along the hierarchy of analytics, the complexity of the analysis increases, but the value of its result also progressively increases.

If we talk about geographically distributed medical organizations in the context of the relevance of the use of big data technologies to support their main (medical), as well as managerial and auxiliary processes [14, 15], the following conclusions can be drawn:

- Big data technologies as support of telemedicine processes play a big role due to the opportunity of providing medical services in remote regions, as well as connecting top specialists from the specific medical center to medical consultations and manipulations realized in other centers situated in different regions.
- Big data technologies as a resource for potential market analysis—this helps with identifying geographic markets with a high potential for growth, which is especially important for commercial medical organizations.
- When a potential market is found, there is a need in effective marketing activities, which big data allows due to collecting and systemizing information about consumers, patients, physician needs, and preferences.
- The larger the geographically distributed medical organization is, the more data it collects not only about patients but also about management processes. Analyzing this data helps improve management decisions, e.g., on drugs & materials logistics, patient flow processes, HR management (especially the processes of continuous training of medical specialists), etc.
- The research activities of geographically distributed medical organizations are seen as one of the main directions of big data technologies application, because of the ability to analyze medical data represented from different regions of the Russian Federation. This makes it possible to find non-trivial patterns, interdependencies, trends, etc., and form new standards and treatment protocols based on the analysis results.

3.3 Case Study: IT Service Architecture for Big Data Usage

The formal structure of the Case organization is represented by several legal entities united under a single brand and functionally managed by a single body—the management company.

The organization has faced the challenge of reorganizing its IT architecture in response to strong growth over the past few years. At the same time, growth occurs both through the construction and opening of new medical centers in different regions of RF “from scratch” and the acquisition of existing (operating) organizations. The management model has undergone significant changes since it became necessary to create a unified management center that could act as a developer of operating standards, as well as a body for strategic and current control of activities carried out in geographically distributed business units. This need was reflected in the creation of a management company.

Tasks faced by the medical organization at the time of the decision on the need to apply big data technologies are:

- The need to integrate disparate information systems used by “acquired” healthcare organizations with systems used in the management organization;
- The need to improve systems that support management functions, taking into account the increasing number and specifics of individual business units;
- The need for analysis of real-time data produced by supporting functions of the organization (engineering, procurement, and logistics, etc.);
- The need to introduce digital services to attract new customers, increase the loyalty of existing customers, increase competitiveness due to a large number of commercial medical organizations with a similar profile of activity.

In accordance with the method of developing the architecture of IT services [2] as a first step, a functional model of the case organization was developed. The result is represented in Fig. 1.

The next step in the application of the method for developing the architecture of IT services for the presented organization was the identification of information needs of business functions. In the process of a dialogue between a business analyst and a manager/representative of each of the functions presented in the model, as well as studying the documentation existing within the framework of the function being performed, a list of information needs was developed. Next, an analysis was made of the capabilities of big data technologies in relation to meeting the identified information needs. Table 1 represents the results of this analysis.

Based on the aggregated information from Table 1 the high-level architecture model [16] was designed, describing data flows from IT applications to the big data engine, as well as analytics results flow back to IT applications, used by business functions. The architecture model is presented in Fig. 2.

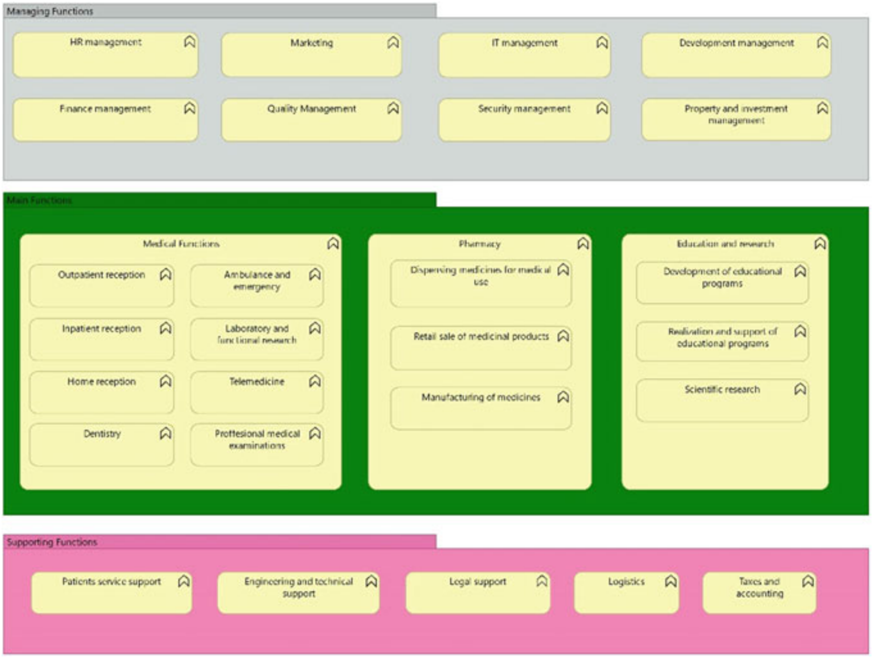

Fig. 1 Functional model of a geographically distributed medical organization

4 Conclusion

The use of digital technologies is becoming an increasingly relevant and demanded task for medical organizations. This is due, among other things, to the increasing availability of such technologies. Geographically distributed medical organizations face a number of management and scientific tasks, the solution of which using big data technologies may be more effective and efficient.

Enterprise architecture approach can be applied to analyze, how to build big data technologies into the complex architecture of a medical organization. The next step of research is to model a detailed IT service architecture of a geographically distributed medical organization with the use of digital technologies opportunities.

Table 1 Ways of applying technologies at different levels

Function	Information requirement of the function	Opportunities of using big data technologies
Development management	Collection and processing of data on market share in the context of segments of medical services and individual business units	Collection of data from social networks and Web, integration of data from different sources (incl. MIS and CRM), intelligent analysis of data
Marketing	Collection and processing of data on market opportunities and consumer behavior	
Quality Management	Collection and processing of data on the quality of medical services	Collection and processing of data (from patients) from various sources about the quality of medical services
HR Management	Collection and processing of personnel data (incl. job seekers) Collection and processing of data on the need for staff training	Building analytical reports in the required sections. Automatic selection of suitable applicants among job seekers according to the specified parameters, taking into account the analysis of data on past interviews with applicants. Automatic staff training scheduling based on real-time analysis
All medical functions	Collection and processing of data on best medical practices	Selection of best practices for specific cases based on analysis of existing data
Laboratory and functional research	Preparation, storage, and processing of medical images. Registration and analysis (interpretation) of the obtained laboratory data	Collection and processing of unstructured data from different laboratory and radiation diagnostics

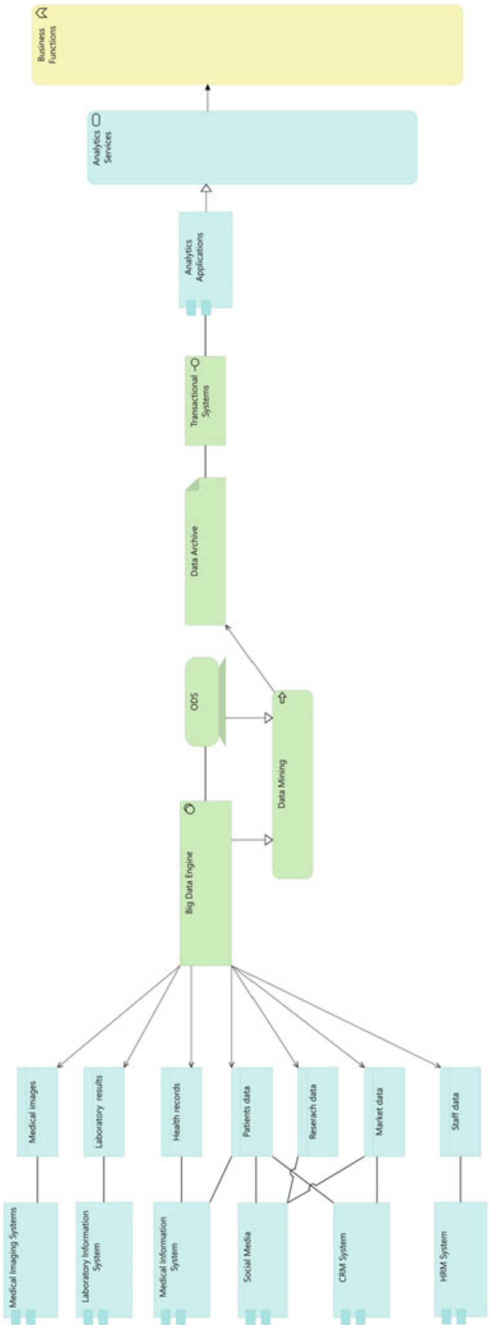

Fig. 2 Enterprise architecture model for using big data technologies in medical organizations

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