THE APPLICATION OF MOBILE TECHNOLOGY MANAGEMENT CONCEPT AND BIG DATA SOLUTIONS IN HEALTHCARE

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Abstract: The aim of the paper is to present the concept of mobile technology management in healthcare. The paper puts emphasis on application of mobile devices in provision of data indispensable for processing it by big data solutions and underlines relation between mobile technology and big data. Nowadays mobile devices generate large volumes of different types of data which can be analyzed by specialized analytical systems. Data analyses based on gathered by mobile devices data and conducted by mentioned solutions technology bring many advantages for patients, doctors and for the functionality of health care units. The paper presents characteristics of information systems of health care units with its division into white and grey part. It further presents the notion and benefits of m-Health and its possible areas of application. The possible areas of big data applications in healthcare units are depicted in the next part of the article. The practical part of the paper embraces the review of selected case studies of mobility management and big data solutions in selected foreign healthcare units.

Key words: Big Data, healthcare management, enterprise mobility management, m-Health

Introduction

Beginnings of mobile technologies are connected with rapid development of mobile telephony, that is cheap and common voice communication with the global range. They are considered as one of the basic factors of healthcare technological support development (cloud computing, social networks and Business Intelligence data analytics and processing are similarly treated). Mobile devices are not only used nowadays in the business and vocational activity of the human, but also for achievement of his consumer aim (Pawełoszek-Korek, 2009). According to Google the number of questions realized by means of mobile devices in the year 2015 exceeded retrievals of desktop computer in 10 countries (Jędrasik, 2015). P. Chabot (report: mHealth, 2013) states that consumers accustomed to high-quality and utilities of mobile services provided by commercial companies expect similarly high-level of mobile services provided by healthcare subjects. Similarly experiences from other commercial lines of business activity of the man connected with mobile technologies can be used by medical professionals.

Mobile medicine (m-Health) embraces all rapidly developing modern mobile technologies used for the purpose of information and services delivery connected with widely comprehended health protection. The comparatively general definition of m-Health is given by e.g. m-Health Alliance organization. According to this organization m-Health embraces all solutions supplying medical services based

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directly on mobile technologies and all other supported in a significant way by these technologies (mHealth Alliance, 2014). The notion of m-Health contains itself in the wider definition of e-Health which means the utilization of information and communication technologies (computers with appropriate software, computer networks, satellite and cellular communication etc.) for the purpose of medical services delivery.

The market of mobile technologies is one of most quickly growing markets of modern technologies. This also concerns utilization of mobile technologies in the healthcare activity. To speed up discoveries of disease biomarkers and treatments, we must work out a cheaper and faster way to process, store and use the huge medical data sets that are rapidly becoming available. By 2015, it is likely that a typical hospital will create 665 terabytes of data a year (for comparison, the web archive of the US Library of Congress contains less than 500 terabytes). This information can be used to study and analyze treatments — for example, for tuberculosis and stroke — and to reduce health-care costs. To handle such big data effectively, we need to adapt classical information-processing tools (Sejdić, 2014).

The main aim of the paper is to presents the concept of mobile technology and big data application in healthcare area.

The Specificity of the Information System of Healthcare Units

In the organizational structure of the healthcare unit can be distinguished two basic parts: medical and administrative. The medical part, defined often as „white", provides medical services. The administrative part called „grey", deals with the business side of the whole organization's activity. IT systems of the organization must refer to its organizational structure.

The grey "part" of the healthcare unit uses IT systems dealing with data processing of business concerning realized services and basic financial and accounting data concerning the whole of healthcare subject's activity. These types of IT systems realize certain subset of functions supporting managerial processes typical for ERP transactional systems. The second group of IT systems is connected with „the white" part of healthcare subject and contains most often (depending on the size and the scope of activity):

− IT systems recording medical data of patients;
− Transactional IT systems recording basic business transactions;
− IT systems supporting management of medicines deliveries, medical resources and other medical equipment inside the hospital;
− Archiving systems and image transmission of which main assignment is the storage and making available images coming from research of imaging character;
− Systems of remote identification of objects (patients, equipments, tools and the medical apparatus, medicines);

- Telemedicine systems, supporting remote and mobile forms of medical services provision among which can be distinguished:
  o telediagnostics,
  o teleconsulting,
  o telemonitoring,
  o medical telerobotics etc;
- Systems supporting management of relations with patients (PRM);
- Systems supporting analysis and reporting (Bal et al., 2005).

The basic activity at the operational level of healthcare subjects (depending on its size) is realized with the support of transactional IT systems integrated is some extent with other domain IT systems of the unit.

The development of information communication technologies, elaborated standards and connected with it growth of interoperatibility enables integration of mentioned above IT systems. The integration of "white" and "grey" part of IT systems is one of the key conditions of efficient management, and indirect development of healthcare subject.

Figure 1 presents possible areas of m-health application and interdependencies between them. It is commonly considered that the application of m-Health allows for:

- extending the reach of healthcare,
- improving the healthcare decision making processes and their outcomes,
- better management of chronic healthcare conditions and
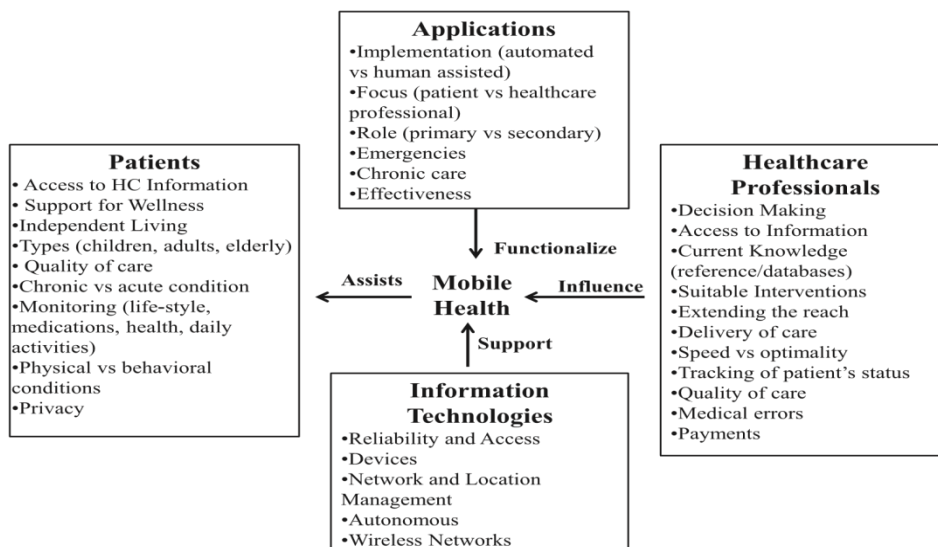- managing emergencies (Chluski, 2009).

Figure 1. Possible areas of m-health application *(Varshney, 2014)*

As it was presented in Figure 1 mobile health is supported in many ways by Information Technologies and assists patients in many dimensions. m-Health technologies can support services which are provided traditionally and also realize new types of services which cannot be provided traditionally.

Possible Areas of Big Data Applications in Healthcare Units

The definition of big data embraces "the practice of collecting complex data sets so large that it becomes difficult to analyze and interpret manually or using on-hand data management applications" (Wang et al., 2014). In the literature of subject big data is defined by the three V's:
− "Volume - meaning large amounts of data,
− Variety - meaning different forms of data, including traditional databases, images, documents, and complex records,
− Velocity - the constant change of data content" (Berman, 2013).
J. Kelly enlists such sources from which big data is generated as:
−   "Social networking and media such as Facebook, Twitter - where structured, semi-structured and unstructured data is generated,
−   Mobile Devices receiving and transmitting different data including,
−   Networked Devices and Sensors e.g. smart energy meters and temperature sensors creating semi-structured log data that record every action" (Kelly, 2014).
The amount of data that is captured by typical healthcare system is classified as "big data", which can be generally defined as "…datasets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyze" (Manyika, 2011) and it is consistent with the presented earlier, more technical definition of big data: "…meets three criteria: volume, variety, and velocity", requiring that the data equate to the size of terabytes or petabytes (10^9 and 10^{12} the size of a kilobyte, respectively). Healthcare data sets contain largely unstructured or varying types of data (i.e., not easily categorized or sorted). Deloitte report states that "for many countries healthcare data has become a national infrastructure priority and attracts significant funding. As a result, patients themselves, clinicians and healthcare officials use healthcare data to transform diagnosis and treatment to improve outcomes and healthcare productivity" (Taylor, 2015).
The mobile devices most often constitute extra access "interface" (apart from "desktop" devices) to the various data sets (Jelonek et al, 2013). Most of the data collected within the healthcare activity has or might in the future have the data character of big data. They may include medical data without the possibility of patient identification and concerning diagnosis, method of treatment and its effects (Frączkiewicz-Wronka and Wronka-Pośpiech, 2014). Such data can be extracted from applications such as Electronic Patient Record, databases created on the basis of obligatory medical records conducted in healthcare subjects in the electronic form. The other data source may be systems maintained and used by

public administration e.g. in the scope of statistical research program concerning public statistics in the "healthcare" part. The other example may include Project P1. The aim of the P1 project is to build electronic platform of public services in the scope of healthcare, enabling public administration offices, entrepreneurs including among others healthcare units, drug stores and medical practices and also citizens to gather, analyze and making available digital resources concerning medical events.

Presented examples of data sources fulfill the first definition criterion of Big data - the large size of databases, exceeding possibilities of service by standard systems of databases. The second criterion (variety) also can be perceived as an accomplished, because data connected with health care activity have very differentiated character. Beginning from data of well-known and constant structure (e.g. financial data, personnel, personal data of patients via figures and textual data of more or less known and established structure (e.g. results of chemical and biological laboratory tests, recordings and textual notes of doctors concerning diagnoses and the course of treatment) till static graphic data (2D and 3D) and video registrations which are the results of image inspection.

The other source of big data can be data connected with community portals concerning health care and the promotion of healthy lifestyle. Due to personal data protection and its private (sensitive) character of medical data the information can be gained in the indirect manner. For example rapid increase of questions on influenza symptoms can be an indirect signal or an alarm before suspected flu epidemic occurrence (Ginsberg, 2009). Another example can be data from the analysis of the activity of smartphone users of sports tracker type applications in the form of „non personalized" statistical data which can turn out to be useful for research of so called healthy lifestyle of different social groups.

Healthcare subjects can gather and process data originating from medical sensors monitoring and diagnostic less or more automated with mobile wireless character.

In the half of the year 2012 approx. 62% doctors and 71% of nurses used smartphones in their own professional activity. There were available approx. 40 thousand of medical applications for mobile phones, tablets and other mobile devices, and 247 millions of people installed at least one mobile application. In developing countries 59% of patients used mHealth application at least once comparing to 35% in developed countries (e-kardiolog.pl, 2013).

The research carried out by Chatterjee (2009) confirmed that both the medical staffs as well as patients use „portable and mobile" devices first of all for communication, input and download of data (as answers to concrete questions directed to appropriate IT systems). The issue of computational capabilities of mobile devices is less essential.

According to Research and Markets (2013) nowadays mobile penetration constitutes more than 100% in developed markets and is rapidly growing in developing markets such as Asia-Pacific, Latin America and Africa. What is more the change is observed from hospital-care to personal-care, as Mobile Healthcare

systems are providing smooth support and care to patients independent from their locations. The appearance of new generation of connected medical devices is making it easier for healthcare providers to serve patients effectively and at a lower cost. mHealth forecast indicates that "mobile medical devices provide appropriate and systematic registration of biomedical signals such as respiratory parameters, glucose analysis, electrocardiogram (ECG) recordings and blood pressure measurements regardless of the location. Mobile health market participants differentiate their product and services with portability, automation, ease of use and customization. It allows e.g. for diagnosing of chronic conditions. Thus, mobile access similarly to healthcare access is expected to become ubiquitous part of healthcare system over next few years all over the world" (mHealth Market, 2013).

Relation between Mobile Technology and Big Data Solutions

The combination of new technologies of mobile medical data collection as well as processing and analysis of these data using Big Data solutions can be very useful for different stakeholders related to the medical branch. The most important stakeholders and potential beneficiaries in this case are: practitioners, researchers from the medical and pharmaceutical industries, pharmaceutical companies, institutions financing public health service and social and political organizations.
Medical data collected by mobile devices is collected and processed for different entities. In many cases such data is commonly collected, so they apply to all patients. They are also characterized by great diversity, different degree of structuring and a variety of formats. Its common feature is the digital form, which enables its transfer and facilitate transformation from different data formats for other ones which are useful in specific cases. This could be, for example, data on current health status and medical history of the patient stored in the form of compulsory electronic medical records (e.g. electronic patient record).
The main aim of such a data collection is mostly documenting the process of diagnosis and treatment. However, the processing and analysis of this data can be useful for different stakeholders due to the fact that a significant part of it has universal character. The universality feature in this case is important from the point of view of methodological correctness of data processing, and particularly in conduct of medical research (lack of statistical limitations resulting from small and not always representative research sample). The universality of gathering certain medical data in electronic form can significantly reduce the costs of research – an access to the research sample is much easier. It also allows for realization of other research not available by applying existing methods.
The property of universality corresponds to the first V – Volume (from the definition of Big Data), a large amount of data. Universality is a kind of precondition of the possibilities of collected mobile data usage. The variety of medical data formats, its different stages of structuring, different levels of interoperability correspond to the second V-definition of Big Data (Variety). Medical data may be characterized by considerable changeability, often difficult to

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predict and estimate (for example, data concerning the state of health of certain communities during the occurrence of various pandemic such as influenza). This corresponds to the third definition V - Velocity.

Another important aspect is automation of collection and storage of medical data and corresponding to it automation of data processing and analysis in Big Data solutions. The working time of medical personnel is limited and precious. Data acquisition should be highly automated and realized as if "by chance", for example while documenting the process of diagnosis and treatment. Such "anonymized" data should be transferred to some sort of central repository, which means to lose its "local" status associated with a particular patient and become "globally" available. By definition Big Data solutions should be useful in this case for the different stakeholders in the medical branch. It especially concerns the ability to handle large data repositories with different formats, including realization to a certain degree of automated processing and analysis of these data.

According to the authors presented above characteristics and properties of the mobile acquisition and data collection in the health care correspond to the essential characteristics typical for Big Data solutions. It constitutes an important prerequisite, perhaps even a necessary condition for further deployment of these technologies in health care.

Enterprise Mobility Management Systems in Healthcare - Review of Selected Case Studies

The advantages of mobility for healthcare concern e.g. faster access to applications as well as to electronic health records (EHRs), clinicians can make better-informed decisions and recommendations more quickly in order to improve patient results. Practitioners can choose the right device for each situation such as tablet at a patient's bedside, a workstation in a prep room, or a smartphone in order to have an access to their apps and information. Healthcare organizations have most of all such benefits as costs reduction and the possibility of care delivery in more places than before (Best practices, 2014). "This new model for healthcare possesses two key challenges for IT - how to ensure a consistent and convenient experience as clinicians and other employees roam across locations, devices and networks; and how to accommodate and adapt to this new work style without sacrificing security, patient privacy, regulatory compliance and IT manageability" (Best practices, 2014).

A good example in such a case may be implementation of Enterprise Mobility Management (EMM) in healthcare units. As an example "Hennepin County Medical Center (HCMC) in Minnesota uses Citrix healthcare solutions to offer employees and clinicians the ability to use any device, anywhere, to access high-performance apps, desktops and enterprise data. By centralizing desktop application management HCMC increases IT efficiency, simultaneously ensuring the end-to-end security necessary to meet HIPAA requirements" (Best practices, 2014). In the mentioned hospital the implementation of EMM system was started

in 2009 year. Currently HCMC gained Stage-6 certification in the EMM Adoption Model for the best use of information technology and management systems (Murphy, 2015).

The other example is "Kaweah Delta Medical Center (KD) in Central California which focuses on the six rights: getting the right information to the right person, at the right place, at the right time, in the right format, to ensure the right value. The hospital used Citrix healthcare solutions to create MyKD, a complete virtual desktop which can be run on any type of computer, tablets and smartphones" (Best practices, 2014). KD is a leading California-based healthcare organization which has been using a combined Citrix and AppSense solution to deliver virtual desktops to their workforce. The first implementations took place in 2010 year (Kitson, 2011).

In Kindred Healthcare "employing 75000 of staff and with $6 billion of revenue the subject uses Citrix healthcare solutions in order to rapidly integrate additional healthcare providers into its organization. Kindred can help people to obtain care more easily even as their medical needs change by moving smoothly among a diverse enterprise of hospitals, rehab centers, nursing homes and other facilities" (Best practices, 2014). Medical personnel of Kindred Healthcare use Citrix® XenDesktop® and Citrix® XenApp™ to deliver virtual desktops and applications to all users so they would have all the resources they needed (Kindred Healthcare, 2011). Kindred through its subsidiaries had approximately 103,700 employees providing healthcare services in 2,730 locations in 47 states, including 96 transitional care hospitals, 16 inpatient rehabilitation hospitals, 90 nursing centers, 21 sub-acute units (kindredhealthcare.com, 2015).

In case of Miami Children's Hospital (MCH) "a Citrix-powered telehealth platform is used to help doctors apply the latest advances in specialized pediatric medical care to improve outcomes and save children's lives. Clinicians at MCH can log into apps and desktops quickly and securely on any device to access the information they need to guide the care they provide. MCH's doctors also use the platform for remote consultation with hospitals around the world, making its advanced expertise available to patients who may be hundreds of miles from the nearest subspecialists" (Best practices, 2014). Miami Children's Hospital is a world leader in pediatric healthcare. With a medical staff of more than 650 physicians and over 3 500 employees, the hospital is renowned for excellence in all aspects of pediatric medical care from birth through adolescence (nicklauschildrens.org, 2015).

Another worth mentioning example is the Medical University of South Carolina (MUSC) which "provides healthcare services to patients locally while supporting doctors and research around the world. The university uses Citrix healthcare solutions to virtualize its infrastructure making it possible to improve delivery of IT services while improving efficiency and significantly reducing cost. With more than 300 applications accessible on any device, anywhere, patients in both urban and rural communities can benefit from the latest advances in medical knowledge" (Best practices, 2014).

The last example where such a solution was put into practice may be Seattle Children's Hospital which "makes extensive technology resources available to its staff, from electronic medical records to databases of clinical information to real-time patient monitoring systems. Citrix healthcare solutions help Seattle Children's Hospital provide a faster, more mobile, and fully transparent computing at a lower cost" (Best practices, 2014).

Conclusion

According to Boston Consulting Group the world market of mobile medical technologies should reach the value of 11.8 bn USD until the 2018 year, comparing to 2.1 bn USD in the year 2011. In the 2016 there should be used approx. 4.9 millions of domestic monitoring health systems communicating automatically with appropriate workers of health care. The number of medical devices, using cellular networks as the basic communication mean should reach 2.47 million (e-kardiolog.pl 2013). However, according to Deloitte experts the global value in 2018 year will be 21.5 bn dol. The strongest market in the m-health segment will be Europe with a share worth of 7.1 bn dol. and average annual growth of 61.6 percent (Tylor, 2015).

Mobile health solutions can further lead to many important advances in healthcare and information technologies. These are proactive health and wellness management, where chronic conditions can be detected and managed much before occurrence of any major complications; design and use of medications that are most suitable for individual patients; healthcare systems that are context aware to provide necessary interventions as needed for health and medications; smart technologies which can sense and support the needs of the elderly in their independent living. Personalized and intelligent monitoring of patients can lead to better health outcomes at a lower healthcare cost. This paper may lead to conducting more research in identified areas and, the proposed framework and high-level solutions are useful in further progress in this mentioned important and emerging field.

Mobile computing and big data are crucial in improvement of healthcare outcomes and quality. Mobile computing acts as both a source of big data and as the channel for distributing information and recommendations from big data. Mobile computing provides data that may be aggregated into big data warehouses with other data, including medical records and demographics. Analytics is then applied to extract information, draw conclusions, spot trends and make predictions that can be shared with healthcare constituents to improve quality and outcomes as well as to increase competitiveness.

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ZASTOSOWANIA TECHNOLOGII MOBILNYCH ORAZ ROZWIĄZAŃ BIG DATA W ZARZĄDZANIU OCHRONĄ ZDROWIA

Streszczenie: Celem artykułu jest prezentacja koncepcji zarządzania technologią mobilną w służbie zdrowia. Artykuł kładzie nacisk na zastosowanie urządzeń mobilnych w dostarczaniu danych niezbędnych dla celów ich przetwarzania przez rozwiązania zwane big data i podkreśla relacje występujące między technologiami mobilnymi a rozwiązaniami big data. Obecnie urządzenia mobilne generują ogromne ilości danych różnego typu, które mogą być analizowane przez wyspecjalizowane systemy analityczne. Analizy danych opierające się na danych zebranych przez urządzenia mobilne i przeprowadzone przez wspomnianą technologię przynoszą wiele korzyści pacjentom, lekarzom jak i samym instytucjom opieki zdrowotnej. Artykuł charakteryzuje systemy informatyczne jednostek służby zdrowia z ich podziałem na część szarą i białą. Następnie prezentuje istotę i korzyści rozwiązania m-Health i jego możliwe obszary zastosowań. Natomiast możliwe obszary zastosowań big data w jednostkach służby zdrowia opisano w kolejnej części artykułu. Praktyczna część obejmuje przegląd wybranych studiów przypadku zastosowań big data i zarządzania mobilnością w zagranicznych podmiotach służby zdrowia.

Słowa kluczowe: Big Data, zarządzanie ochroną zdrowia, m-Health, zarządzanie technologiami mobilnymi podmiotów leczniczych

移動技術的管理理念，在醫療保健大數據的應用解決方案

摘要：本文的目的是展示移動技術管理的理念在醫療保健。文章提出的申請中提供的數據不可缺少的通過大數據解決方案，處理它的移動設備的重點，並強調移動技術和大數據之間的關係。現今的移動設備產生大量不同類型的數據，可以由專門的分析系統進行分析的。數據分析的基礎上收集的移動設備上的數據並提到解決方案的技術實施帶來諸多優勢，為患者，醫生和衛生保健單位的功能。本文介紹了醫療單位的劃分信息系統的特性分為白色和灰色的部分。它還提出的概念和M-健康和其應用的可能領域的利益。在醫療衛生單位的大數據應用的可能領域被描述在文章的下一部分。本文的實踐部分包含了移動性管理，並在選定的外國醫療單位的大數據解決方案的選擇案例的審查。

關鍵詞：大數據，醫療管理，企業移動管理，移動醫療