Smart healthcare for smart cities

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Abstract

The proposed goals of smart cities are to improve the quality the life of citizens by improving urban infrastructure, foster innovation and enhance the healthcare system offered to their citizens. This paper presents a literature review about the use of Big Data Analytics and BDA-related technologies in order to provide highly efficient medical and health services to patients living in smart cities. A lot of tools in Big Data Analytics involve data mining; thus, we are proposing a simple way of collecting medical and health-related data from patients using a series of sensors and a cloud-based method of mining, transmitting, and analysing data using a (hypothetical) machine learning system. As a conclusion, we may say that health services in smart cities and the use of big data mining for improving medical decision support, among other aspects of health and medical care services are (almost) purely theoretical concepts at this point. These services definitely look good on paper, but there is yet to be a truly successful model that has been tried in real-life clinical practice that has, at the same time, been unanimously considered as successful.

Keywords: *Big Data Analytics, Healthcare services, Smart Data.*

1. Introduction

The impacts of information technology innovations such as Big Data Analytics (BDA) are now starting to reach industries that have long been considered as slow adopters, a perfect example of which is the health care industry [1, 2]. It can be recalled that it took at least a few decades before the health care industry started to break free from the traditional pen and paper-based methods of record keeping in

favour of higher-tech and digital-based means of conducting record-keeping operations. While organizations in the health care industry were still thinking about whether digitalizing their patient and medical and health personnel's records would be the right call or not, a consistently growing number of technologies and innovations were already being introduced in the background. One of such is Big Data Analytics; thus, the objective of this paper was to conduct a literature review about the use of Big Data Analytics and BDA-related technologies to provide highly efficient medical and health services to patients living in smart cities.

2. Literature review

Big Data Analytics can be used in the health care industry in numerous ways. There are, in fact, some studies that have been published in the past about the different use cases for BDA in the aforementioned industry. In general, Big Data Analytic methodologies such as data mining and knowledge discovery, can be used to collect, analyse, and leverage consumer, patient, clinical, and other types of data that may be considered too vast or complicated for individuals using traditional means of data processing (even with the help of computers) to understand [3, 4].

More specific types of BDA such as data mining and knowledge discovery, harnesses the power of computers not just to assist the person conducting the analysis perform his duty. In a typical BDA scenario, there are the computers that are actually doing the complex computations already; they also involve little to no human intervention and or interaction [5]. This is often done via a combination of machine learning, artificial intelligence and data science.

From a broad perspective, BDA can be a highly efficient means to enable public and private entities that are operating in this industry to make better decisions. Such decisions may be better than the ones that the leaders of the public and private entities may be able to make without the guidance provided by the Big Data Analytic tools (e.g. data mining and knowledge discovery programs) in various ways.

Some decisions, for example, may have a positive impact on the overall patient experience, while some may be more focused on bringing the level of accessibility of the available health care services up to, especially to those who really need them [6, 7]. In the majority of the cases, however, the improved outcomes of the decisions that medical and health care institutions that would end up using BDA tools such as data mining and knowledge discovery would most likely be attributed to their newfound ability to be more aware of their situation and surroundings [8]. This increased level of awareness is what enables them to make more precise adjustments in the areas that require improvements [9].

2.1. Personalized medical and health care services in smart cities using big data analytics infrastructures

There is a high degree of variation when it comes to the type of medical and health care services that a person is going to need [10]. Medical and health care

professionals always point out that every patient's case is different [11]. This is still true even in cases where two or more patients have been diagnosed with a similar disease or disorder. This is where the importance of a medical and health care institution's ability to provide highly personalized services to their patients come in. The problem, however, is that highly standardized (and at some point, mass-produced) medical and health care services are already expensive as they are to the point that even the people who really need access can barely afford them.

Affordability will undoubtedly be an even bigger issue if medical and health care institutions are to start offering personalized care to their patients [12]. The good news is that this problem can be solved through the adoption of smart technologies, mainly big data analytics, in medical and health care practice. In a study that was featured in the IEEE International Symposium on Medical Measurements and Applications, for example, Patsakis et al. (2014) suggested that the wide deployment of various types of diagnostic sensors in various parts of the city would be an effective way to collect data about the overall health and medical conditions of the patients or people who live or work inside the designated smart city grid. The purpose of the sensors is to collect data about their medical and health condition. These data would then be stored and analysed through data mining and knowledge discovery applications – which is precisely where the Big Data Analytics aspect of the process comes in. This, according to Patsakis et al. (2014), is a good way to improve the specificity and quality of the medical and health care services that the patients living in highly urban areas (that have a huge potential for being converted into a smart city) can receive, without having too much of an impact on affordability.

2.2. Data acquisition from sensors

One of the requirements of a data mining and knowledge discovery-based processes of delivering health services in a smart city is an efficient and not to mention an ethical way of collecting data from a target population – i.e. patients living in a smart city [13]. It is important to note that Big Data Analytics only works if one actually has access to a large stream or pool of data that can be analysed. A typical characteristic among many conceptualized smart cities (because there is not really any full-pledged smart city on the planet at the moment) is a high degree of automation. A truly BDA-inspired way of delivering health services to a large number of people living in an urban area (i.e. smart city) is the remote collection of the patients' medical and other health-related data [14].

This can be done through a wide range of sensors. The important thing is for these sensors to accurately mimic the different methods that physicians use to conduct a physical and medical (non-laboratory) examination of their patient [15]. The overall physical and medical patient examination process can be broken down into four parts. Each of these four parts can be represented by a unique type of sensor that would collect data remotely for the physicians to gather the data that they need to be able also to make a diagnosis or even do a simple check of the patient's status.

These four parts are 1) Inspection, 2) Palpation, 3) Percussion, and 4) Auscultation. During the inspection, the physician basically checks the patient's condition using his eyes, to determine if there are any visible signs of trauma, infection, among other potentially abnormal findings. The type of data that has to be accessed through inspection-based examinations can be collected by cameras [16]. In the case of a big data analytics-based system that can perform thorough visual checks on patients, the cameras would act as the physicians' eyes, doing most of the data mining processes for them, and remotely at that. Percussion is another type of examination that can be mimicked by another type of sensor. This type of sensor must be able to record and deliver auditory data from the patient to the receiver. For most applications, a sensor-equipped with a high definition microphone would fit the description. However, it is essential to note that in order to generate recordable sounds, the patient has to be taught how to percuss the potentially problematic areas of his body properly.

2.3. Data pre-processing and transformation

In a clinical setting, it is usually the physician who performs the percussion (tapping). The two remaining parts of physical and medical examination, auscultation and palpation, would most likely be prohibitively invasive (on the patient's part) if it were to be implemented based on a BDA-method. Auscultation requires the use of a stethoscope to listen to the sound generated by the patients' organs (e.g. lungs); palpation requires physical contact between the physician and the patient. There are currently no reliable technological means to mimic these two remaining processes. The ethical issues involved in using a sensor that would have to be directly implanted into a patient's body in order for the said sensor to fulfil its role are also going to be a problem [17].

Sensors that are equipped with specialized hardware that would enable them to perform urine stool seamlessly and even blood analyses may also be incorporated in the smart city health services provision system. This would enable the medical and health care institutions to remotely monitor their patients' medical and health conditions, with a high level of precision, as if they are only staying in the hospital [18]. From a realist's standpoint, however, it is essential to recognize that a high level of patient education would be needed in order for this kind of smart health care service provision system to work. A patient, for example, would have to know how to use and or interact with the sensors in order for them (the sensors) to do their job correctly – to relay the data collected from the patient to the data mining computers – for knowledge discovery purposes.

2.4. Data transmission for central servers

The data obtained from the sensors would have to be transmitted to a central database located within the vicinity of a hospital or any designated medical facility. In a study that was published in the International Journal of Healthcare Management ([21]) we have used a rather complicated XML-based process of collecting, processing,

transforming, and transmitting data. While the idea was indeed noble and highly detailed, it creates some unnecessary steps that only complicate the system. Data transmission of sensor-collected patient medical and health data can be freely transmitted over the cloud [19, 21]. This would, of course, entail a certain fee, depending on the overall space that the data that would have to be transmitted would occupy. This space in the cloud would then act as the central server from which the hospitals and medical institutions can access the patients' medical and health data that they have to use as the input in their data mining and knowledge discovery systems. This eliminates the need for them to acquire and set up central server hardware on their own.

2.5. Data reduction

Data reduction processes can be added as a layer to simplify the process of data mining and knowledge discovery. The good news, however, is that the sensors can already be programmed in such a way that they would already be able to transmit the right data so that the need for the addition of another layer (for data reduction) in the system would be minimized, if not completely eliminated.

2.6. Feature and knowledge extraction and visualization

Feature and Knowledge Extraction and Visualization can be performed through the use of machine learning. The machine learning system will have to be fed with the data that have been collected from the patients in order for patterns and trends to start emerging. These can then be used to make better decisions for a group of patients, or even a single patient-enabling the practitioners to provide a highly specific and specialized type of care.

2.7. Decision tree and random forest

The decision tree acts as a layer that enables the users of the BDA tool to determine what the best possible options for a patient or a group of patients are, considering the type of data that have been collected and analysed starting from the sensors up to the part where machine learning systems were used to spot any problems or issues with their health or medical condition.

3. Methodologies used

In this paper, we have used a short literature review that consider the opportunities involved in the development of a health service provision system that is based on the concept of smart cities, particularly Big Data Analytic tools, such as data mining. Here, we have proposed a simple way of collecting medical and health-related data from patients using a series of sensors and a cloud-based method of mining, transmitting, and analysing data using a (hypothetical) machine learning system.

4. Conclusions

The implications of using BDA in the context of smart health services and smart cities boil down to whether the system that the first few organizations would come up with can really do their job or not. The only thing that would convince the patients to try something this revolutionary out for real is if it works.

Big Data Analytics, while a relatively new technology, is already being used in a growing number of industries. Some of the ones that are in the forefront are those operating in the technology and business intelligence industries (e.g. those whose core operations include marketing, advertising, and market research). Big Data Analytics refers to the group of technologies that cover the complex process of analysing large chunks of data, in an attempt, to better make sense of what they mean. Depending on the purpose of the entity that sanctioned the use of Big Data Analytics to analyse data, it often involves the recognition of specific patterns, and trends, that can (presumably) help said to fulfil its role. Assuming that that entity is a business, for example, the pattern and trend recognition-mechanisms of BDA can be used to develop and gain a better understanding of the consumers. This is a strategy that can also be used to deliver more efficient and cost-effective health services, especially within the context of developing smart cities. In conclusion, the authors found that health services in smart cities and the use of big data mining for improving medical decision support, among other aspects of health and medical care services are purely theoretical concepts at this point. They definitely look good on paper, but there is yet to be a truly successful model that has been tried in real-life clinical practice that has, at the same time, been unanimously considered as successful.

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