Leading Advances in the Utilization of Big Data in the Healthcare Industry

“ It is clear that applying data analysis, using the very latest technology, to this massive and increasingly complex data is going to open up new possibilities in healthcare. ”

Professor Tomohiro Sawa, MD, Ph. D.

Introduction

Today, making use of Big Data is becoming mainstream in various industries and business sectors.

The healthcare industry is no exception. In particular, medical facilities, which generate and process huge volumes of medical information and medical device data, have been accelerating Big Data utilization.

In this white paper, Professor Sawa, of Teikyo University Medical Information System Research Center, explains the current state of Big Data utilization in the Japanese healthcare industry focusing on these three specific aspects: data, technology and science. This paper also examines solutions provided by Microsoft* and Intel that support Big Data’s underlying technologies.

We hope this white paper will assist healthcare professionals who are considering how to leverage Big Data by providing guidance on gathering relevant information and evaluating the deployment of a Big Data system.

The Value of Big Data for Medical Facilities and the Technology for Its Utilization

Healthcare Providers and Systems Supporting Medical Facilities

The people and environments associated with healthcare, and the systems they utilize, are all interrelated. Figure 1 on the next page is an overview of these relationships.

Focusing on the people involved, we see the patients and medical team, including doctors, nurses and other healthcare providers. These stakeholders have their own environments that include medical facilities, such as hospitals, as well as the living environments of the patients and their families. Standard at medical
facilities are Hospital Information Systems (e.g. Electronic Health Records and Physician Order Entry Systems) and educational frameworks to improve the skills of medical staff. All of these interconnected entities – people, environment and systems – work together to enable medical services.

Among these systems, EHRs, Decision Support Systems and robots used by surgeons serve as important interfaces between the healthcare providers and the medical systems.

Almost all hospitals in Japan have been “analyzing” data stored in the Hospital Information Systems using spreadsheets by hand. In general, this analysis goes no further than statistic aggregation – determining the number of outpatients in the last month, the number of inpatients on a given day, the mortality rate, etc. What is really needed is for the relevant healthcare providers to have access to this analytical data interactively and in real time. Technological assistance is indispensable in making this possible.

Hospitals in 2010

Figure 1

Hospital Information Systems are indispensable to the hospitals of today. They play a crucial role as information interfaces for doctors and nurses. A Hospital Information System consists of Electronic Health Records (EHR), a Provider Order Entry (POE) System, a Medical Accounting System, a Picture Archiving and Communication System (PACS) and so on.
The Value of Big Data for Medical Facilities

Now, let’s consider the value of Big Data for medical facilities by focusing on three key aspects: data, technology and science.

**Data**

Well-known medical data includes blood test values, electrocardiograms (ECG) and X-rays (X-P). Clinical diagnostic tests will extend from the level of organs and tissues to a greater use of cells and genomic data. Data is changing in both volume and variety. For instance, the increasing use of color video and echo images, alongside traditional still images, has led to an improvement in the quality of clinical data. At the same time, volumes have been rising so dramatically that they have been surpassing the handling capacity of existing information systems.

It is clear that applying data analysis, using the very latest technology, to this massive and increasingly complex data is going to open up new possibilities in healthcare.

Genomic Data: Clustering Large Volume Data.

For example, let’s look at genome analysis technology. Figure 2, below, shows the changes in annual costs for genome analysis according to the National Human Genome Research Institute (NHGRI). With the year 2008 as the turning point, and more steeply than Moore’s Law, costs have shown a rapid decline. The reason for this is that the underlying technology used in genome analysis has made considerable progress. Clustering algorithm is used to analyze massive amounts of genomic data yielded by the technological advances. Clustering technology has become indispensable to life science, and is supported by database and analysis services.

Genomic data analysis has shown that a type of leukemia, which was once considered to be a single type of disease, can be grouped into two types, one with a better prognosis than the other. Before too long, it will be possible to match a genomic analysis result with a patient’s medical records retrieved from the Hospital.

![Cost Per Genome](http://Genome.gov/sequencingcosts)

**Figure 2**

Information System, thus employing genomic data in daily medical activities. These processes can be accomplished only by combining clinical data and genomic analysis data, and Big Data technology is indispensable to the processes.

**Life Data: The Utilization of Big Data from Social Network Service (SNS) has already begun.**

Big Data, such as SNS, is beginning to be used in the analysis of life data gathered from patient living environments. For example, SNS was utilized to recruit patients for a study examining the effectiveness of lithium in treating the intractable disease called Amyotrophic Lateral Sclerosis (ALS). It is very hard to collect patient data of rare (only 1-2 patients per 100,000) diseases like ALS. There is a report saying that the clinical study went smoothly by collecting large amounts of patient data from around the world through SNS.

The relationship between the patients and the hospitals (for example, the hospital visit cycle) used to be sporadic – people visited the hospital when they got sick and stopped visiting once cured. Today, there is an emphasis on proactively improving lifestyle to prevent illness and to maintain good health. Now, the 4 Ps - Prediction, Prevention, Participation and Personalization - are of key importance.

**Disease and Health Are Not Opposites.**

Diseases, as treated by hospitals, have very clear definitions, diagnoses and treatments. Health, on the other hand, is viewed from various standards of value and consists of various concepts. As a matter of fact, health related data and indices vary. Instead of considering health as the opposite of disease, we should recognize that disease and health coexist on a spectrum. Some diseases are temporary and some are chronic and lifelong. Measurements of the various aspects of health and disease provide us with a broad array of valuable data. IT can play a critical role in helping us translate this data into information we can use in our daily lives to improve our health and manage disease.

**What is Health?**

The concepts that constitute “health” are diverse. Therefore, the data and indices representing “health” are also diverse.

![Health](image)

Figure 3
Leveraging Data In Telemedicine

Telemedicine is also gaining greater attention. Medical devices used for the management of medical care mainly use an HL7* interface protocol, while the Continua* protocol has been widely used for healthcare devices. Healthcare devices, including manometers, thermometers, and blood sugar meters, are comparatively reasonably priced, are widely used in ordinary households, and are good enough for health maintenance and disease management. Data streams from such devices contribute to the upsurge in data volumes.

Technology

In the same way that patient monitors indicate a person’s physical state, Hospital Information Systems can measure the state of hospital management. They monitor the hospital’s current status by examining such items as the characteristics of the day, the number of patients and the probability of incidents. Technology enabling the high-speed processing of large-volume (Big) data can be put to good use in situations like this.

Currently, more than a few old-fashioned hospitals are still attempting to compile and draw meaning from superficial metrics. For example, a hospital might review, by department, the total numbers of outpatients and inpatients for a previous one month period and then conclude that “internal medicine is doing its best, but surgery is slacking.” There are even cases where hospitals, without understanding the real reason for the increase or decrease in the number of outpatients, end up deciding they should “strive to boost sales by 20%.” In order to advance even one step forward and away from this kind of situation, it is important to make proper use of IT, that is, the Hospital Information System.

Generally, statistical data used by hospitals includes total numbers, such as “2,325 patients today.” Ideally, these totals should be collections of individual data that allow you to drill down to the raw data. It is important to be able to capture both the latest and the past status interactively. The more accurately future developments can be predicted, the greater the value of the data becomes. Being able to drill down
interactively to the granulated data will allow the hospital staff in charge to better understand the current status of their departments and to use the data in carrying out their duties.

For example, if we look at the mandatory disease registration procedure conducted at all hospitals, we see that it is possible to track progress interactively using Business Intelligence (BI). The system is designed with a star schema, the diagnoses are entered into the fact table, and the month, medical department, and categories of diagnoses are placed in the dimensions.

Intuitive Analysis of Patient Cases with Business Intelligence (BI). BI technology can be applied to the analytic system utilizing the star schema described above. With registered diagnoses, it enables interactive assessment of the current state of development for allergies, respiratory tract infection (RTI), chronic disease, gastroenteritis, and so on. For example, specifying the key term “allergies” shows results of sharply rising allergic conjunctivitis and allergic rhinitis in hay fever season in spring (Note: Results of the analysis below are displayed in real-time powered by SQL Server* 2012 SP1 and Power View* for Excel* 2013.)

Category: Allergies

Figure 5
If we look at respiratory tract infection, we see that the peak is in February, since the major cause is influenza.

All of the data analytics shown above have been made possible using BI technology in conjunction with Excel. For large hospitals, where data volumes exceed Excel’s capability, SSAS (SQL Server 2012 Analysis Services)* provides analytics. This interactive approach facilitates a multidimensional analysis that enables users to look at data from various perspectives – a significant improvement over the traditional method of reviewing printed summaries.

**Figure 6**

The Japanese Society of Anesthesiologists (JSA) gathers and stores anesthesia statistics from anesthesiologists in over 1,000 medical facilities in Japan, encompassing about 1.4 – 1.5 million cases. Over 400 facilities provide the data in digital format. More than 3 million data entries are currently stored in the database.

Anesthesia has become safer than it was 20 years ago. For instance, 20 years ago, the number of deaths per 10 thousand occurring within 7 days after undergoing an operation exceeded 8 cases. In 2011, it decreased to 3.14. In real medical practice, such general metrics have limited utility. What really matters is patient-specific information. For this reason, it is necessary to revise the general approach to make it more patient-specific.

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Risk Calculator for Population of 700,000 Patients

Figure 7

Risk Calculator for Patients with Caesarian Operation

Figure 8
In another example, general statistics may indicate that of an annual total of 700,000 patients who underwent similar operations (Figure 7) there were 204 post-operation deaths. Individualized statistical information that considers factors such as patient age, gender and pre-operative health condition would be much more meaningful.

If you checked for those who died after being forced to undergo a Caesarean operation in the sample database, you would find that of 8,839 healthy pregnant cases (Figure 8) there were no deaths. If patients can be provided with information that is more relevant to their own specific circumstances, they can undergo surgery with more realistic expectations.

As explained above, systems can be effectively leveraged to provide patients with individualized information that is relevant to them personally and that addresses their main concern, which is “What about me?”

**Science**

Here are a few practical examples.

A hospital’s current state – how busy it is and what activities it is engaged in – can be ascertained from three numbers in the Hospital Information System: accesses to the HIS, input characters and orders.

- **Number of Accesses:** The number of accesses to the Hospital Information System.
- **Number of Input Characters:** The number of characters input into the EHR.
- **Number of Orders:** The number of orders issued when initiating medical actions.

Cluster analysis shows there are approximately 10 clusters. Clusters 1 to 3 are concentrated on weekdays. For days before holidays the clusters are different since the pre-holiday outpatients are increased (cluster 7). Clusters for long holidays are different from clusters for Sundays or single-day holidays (clusters 5, 6). Patterns for

**Clustering 365 Days in a Year**

“What does it look like today?”

- # of Accesses to HIS
- # of Input Characters
- # of Orders

Weekdays

Cluster 3

Cluster 1

Cluster 2

Cluster 8

Monday or the day after holiday

Friday or the day before holiday

Saturday

Cluster 4

Cluster 7

Cluster 10

Cluster 6

Cluster 5

Sunday or single holiday

Consecutive holidays

Figure 9
Saturdays are clearly different since outpatients are accepted only in the morning (cluster 4). After long holidays or on Mondays, more patients visit the hospital than on other weekdays, and this is a separate cluster (cluster 8).

**Weekdays:** Clusters 1, 2 & 3 include data only for weekdays and no data for holidays or weekends. On weekdays, the number of outpatients is around 2,000, with each day having roughly the same number. About 80-90% of the 1,150 beds in the hospital are constantly occupied. The numbers of accesses, orders and input characters in the morning and those in the afternoon are almost equal, the distinguishing feature of weekdays. On weekdays, also, the number of outpatients in the morning and that in the afternoon is almost equal. A cluster is formed by gathering days with the above pattern.

**On Saturdays:** Cluster 4 includes data only for Saturdays. On Saturdays, outpatients are accepted only in the morning. The number of accesses and orders decreases by 60-70% from Saturday morning to afternoon due to the limited outpatient hours. This fact possibly defines the feature of Cluster 4.

**On consecutive holidays**, the hospital accepts only emergency outpatients. The number of inpatients is reduced to one-third of normal weekday figures.

As explained above, with just a look at the three indexes - accesses, input characters, and orders to the hospital information system—the hospital’s patterns are clearly evident. The effective use of cluster analysis enables you to visualize a hospital’s activity patterns.

The following is an example using Hadoop*. Hadoop works very well for network analysis. While it is not easy to store or set relations in a relational database management system (RDBMS), it can be built efficiently when using the Hadoop platform.

Figure 10 shows the relations among medical staff. The doctor places an order with a nurse, and the nurse treats the patient. The doctor also places an order with the pharmacist, who then dispenses a drug, and so on. The medical staff and patients are connected to each other through medical activities. Applying network analysis to massive volumes of data enables you to understand the hospital’s social structure and develop an internal relational graph.

![Figure 10](image-url)
A relational graph helps you to understand the difference between the social relationship patterns on weekdays and holidays. On a holiday, medical care is mainly focused on the inpatients. Figure 11, above, shows that multiple doctors (orange) and nurses (green) care for one patient on a holiday. We might say that a medical team cares for one patient. On weekdays, the ratio of medical staff to patients is completely different due to the fact that outpatients also are receiving care. Even if you are experientially aware of the numbers, this gives you a more intuitive understanding of how they are interrelated.

This kind of analysis can help identify an overwork situation for specific doctors and nurses and may help management correct the situation before overwork begins to affect operations.

**Technical Issues Regarding Existing Data Analytics**

In recent years, Hospital Information Systems have become popular. Issues that may arise for hospitals, after a system has been deployed, include medical staff disillusionment because they do not perceive a benefit from the system or management dissatisfaction with the system because they do not realize a return on their investment as quickly as desired.

Current data type of hospital information systems are not significantly different from the past, but the technology for retrieving data and presenting it graphically has been vastly improved. Past technology basically allowed you to represent data as a numerical list, which is hard to grasp intuitively. Even if the core data itself is unchanged, the latest technology’s graphical presentation and interactive data manipulation capabilities are far superior to those of the past.
Traditional analytic systems were not easy to deploy in an organization with a limited budget. In addition, the hardware capabilities of legacy systems were insufficient for advanced analysis and graphical presentation which required more computing performance and memory capacities.

It is notable that, unlike in other industries, practical understanding of medical service is the key to medical data analysis and modeling. Only licensed medical staff, including doctors and nurses with medical knowledge and skills acquired through years of practice, can truly understand medical service. In the past, a wide range of vendors and consulting firms proposed large scale analytical systems, visited hospitals, and touted their ability to consult on the construction of a medical data model. Few of them succeeded, largely due to their lack of understanding of medical data and practice.

Although medical staff could easily have come up with solutions based on their intuitive understanding and deep knowledge of medical data, their knowledge of data analysis technology and their science literacy were lacking. If they had had an easy-to-use system and had been able to use it, ad hoc, with raw data, they likely would have been able to overcome this obstacle through trial and error.

**Applying Microsoft and Intel Technology to Medical Facilities**

Microsoft and Intel technologies are now being widely applied to the medical sector and are providing practical solutions to meet the demands described above. The products from both companies are making a significant contribution as a system infrastructure capable of high-quality graphical presentation of analytic results and high cost performance for large-scale data processing. A large number of hospitals are now beginning to leverage their technologies in various departments.

**Microsoft Technology**

Microsoft's technology includes Windows* OS (including embedded OS), Excel as a front end, SQL Server 2012 Analysis Services (SSAS)* for RDBMS with BI, Power View* in Excel, allowing ad hoc reporting, and SharePoint* for content management. Collaborative utilization of these products simplifies data analysis for Big Data and enables intuitive reporting.

Excel combined with SQL Server provides great benefits to users. SQL Server, which includes a database engine and all essential BI functions such as Integration Services, Analysis Services and Reporting Services, provides extremely high-performance data analysis without additional capital spending. SQL Server is quite easy to manage, and allows configuration using scratch building. File detach and attach is simple, so even if a build fails it’s possible to use other files. This is very hard to do with other DBMS.

<table>
<thead>
<tr>
<th>SERVICE</th>
<th>OVERVIEW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integration Services</td>
<td>Data Integration (Extract, Transfer/Modify, Load) / CDC for Oracle</td>
</tr>
<tr>
<td>Analysis Services</td>
<td>In memory Column-Store DB for BI, DB/Multi-Dimensional DB, Data Mining</td>
</tr>
<tr>
<td>Reporting Services</td>
<td>Reporting capabilities with rich Graph, Map and Sparklines</td>
</tr>
</tbody>
</table>

The ad hoc reporting capability is another benefit for users. SQL Server (2012 SP1), together with Excel 2013 Power View, allows you to generate reports interactively. As described in “Intuitive Analysis of Patient Cases with BI” in the Technology section above, with intuitive reporting users can refer to various segments of a case by dynamically changing its perspective, or can drill down to details.

**Intel Technology**

Enhanced processor performance is the most remarkable aspect of Intel’s technology. The Intel® Xeon® Processor LGA2011® with 64GB RAM enables analysis which was previously thought to be impossible with earlier PCs. Intel® Solid-State
Drives (Intel® SSDs) are also vital for Big Data environments, as well as for the enhancement of overall system performance and the ability to correspond to expanding data volumes.

More departmental systems are now virtualized in the Hospital Information System. When each system’s images and data are stored in SSD, it is possible to recover promptly from system failures. The utilization of SSD and hard disk is optimized according to the application. SSD is mainly used for transactional applications demanding high performance or for vital signs monitoring requiring second-by-second response time. Hard disk is used for applications that demand mass capacity but are not so performance sensitive in order to optimize cost effectiveness.

**Future Trends in Technology: More Advanced Data Utilization in Healthcare**

We forecast the continued advancement and technological evolution of Decision Support Systems in healthcare. For medical staff today, timely information gleaned over their PCs from Hospital Information Systems, such as EHR and Provider Order Entry Systems, is becoming indispensable. Doctors currently base their diagnoses and treatment plans largely on information derived from patient interviews. As Decision Support Systems evolve, providing greater and easier access to timely data and alternative case studies, doctors will be able to make better informed decisions.

We also forecast that classification and clustering algorithm, which are now just part of BI capability, will emerge as one of the most effective analytical methodologies for data mining. Clustering related data, such as clinical history and treatment data, all together will enable higher quality medical decisions. All the information related to patients including observations, past histories, and treatment will be integrated proactively and processed automatically at the back end.

For data processing, we have high expectations for Hadoop’s Big Data capabilities, as well as RDBMS including SQL Server. We also understand that Apache Giraph®, graph-processing algorithms in Hadoop, is extremely effective for visualizing data that is difficult to process in traditional RDBMS.
Conclusion
The leveraging of Big Data is accelerating in healthcare. What is required for further advancement of medical care is analysis based on integrated data, such as clinical data and genomic analysis data, life data including SNS and other data, and data collected from home healthcare devices for remote medical care and disease management. To date, these types of data have been processed separately.

Big Data utilization relies heavily on information technology and science. Many have great expectations for technologies related to graphical analysis/reporting and high performance data processing for today’s ever-expanding data volumes.

Microsoft and Intel are dedicated to providing ever more meaningful solutions to support efficient and high quality medical care.

Appendix: Background Technologies
This section focuses on technologies provided by Microsoft and Intel, including functions, services, and solutions which are deemed to be of particular value in medical practice.

Microsoft Excel for Intuitive Analysis
Microsoft Excel is generally regarded as a tool for processing data using a simple file format. However, Microsoft has been positioning Excel as a BI tool that can be kept at hand and allows the user to analyze any type of data including external social data. All staff in the hospital, as well as data scientists, are aiming to use Excel as a data analysis platform that will enable them to extract and analyze that data from within Big Data that is most pertinent to their work.

A variety of functions aimed at data analysis have been built into Excel:

Conditional Formatting and Quick Analysis Lens
With Microsoft Excel's Conditional Formatting, you can create intuitive formats by adding specific conditions in Cell Rules. For example, it allows you to color code cells for outpatients so you know when the date of their next visit is approaching. In addition, you can define a conditional format by double clicking the Quick Analysis Lens icon that appears when you select data.

Power Map and Power Query
Power Map and Power Query accelerate utilization of open data sources. You can explore data...
from websites and display the results graphically while correlating it with map data. Figure 13 shows reservoir levels based on the public data provided by Ministry of Land, Infrastructure, Transport and Tourism (MLIT), and makes it easy to intuitively and quickly determine the relation of each region on the map and its water level.

**Slicer**

In Microsoft Excel 2010 and later, you have the option to use slicers to filter data. Slicers provide buttons that you can click to filter PivotTable data. In addition to quick filtering, slicers also indicate the current filtering state, making it easy to understand at a glance what exactly is shown in a filtered PivotTable report.

**Power View**

Power View is an interactive data exploration, visualization, and presentation experience that encourages intuitive ad hoc reporting. Power View is a feature of Microsoft Excel 2013, and of Microsoft SharePoint Server 2010 and 2013 as part of the SQL Server 2012 Service Pack 1 Reporting Services Add-in for the Microsoft SharePoint Server Enterprise Edition.

For example, the director of the hospital can confirm the general status of the hospital using the dashboard and will notice departments in red indicating their KPI is under the predefined value. The director may also drill down through the data related to those departments to get further details and to identify the causes, then compile a report on the findings and send it out simultaneously to all parties concerned. In this way, with Power View, the user (the director) can identify and analyze the data or interactively compile a report without having to rely on the IT department.

**Microsoft SQL Server + SharePoint: Providing User-Specific Content**

Users in hospitals have a variety of jobs, each with different roles. Microsoft SQL Server together with Microsoft SharePoint enables you to provide content suitable for each of these different roles. For managers who may not have enough time to analyze data carefully, there is a dashboard showing daily KPI achievement status in graph form. For power users such as doctors or technicians, cube-shaped data is provided that permits detailed analysis in relation to special patients and diseases and, where necessary, can permit analysis using Excel PivotTables. For general users such as administrative staff, more job-specific content can be provided, such as automatically generated reports on such things as the number of outpatients on any one day or hospital bed turnover rates.

**Microsoft SQL Server: Seamless Cloud Collaboration and Ultra-High Performance In-Memory Technology**

The Microsoft SQL Server 2012 architecture and license can be adapted to a wide range of infrastructures from on-premise to cloud. Without modifying the system architecture, SQL Servers used in hospitals, by means of seamless integration, can utilize cloud environments (for example, Windows Azure*). SQL Server 2014 includes a new in-memory online transaction processing (OLTP) engine as standard that delivers truly breakthrough transactional performance capable of handling Big Data.
Intel® SSD

As a high-performance hard drive alternative, SSD overcomes a key obstacle by bringing vastly improved storage performance to your PC. SSD is based on a NAND flash controller with DRAM as a buffer. High I/O performance is possible since the seek time and search time needed when using a hard drive are not necessary. This offers advantages in massive data processing for Big Data and brings benefits to the PCs used in hospitals in terms of quicker booting, better performance, and less susceptibility to vibration. Intel announced its newest SSD product, the Intel SSD 730 series, for consumer use on March 13, 2014.

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2 Intel processor numbers are not a measure of performance. Processor numbers differentiate features within each processor family, not across different processor families. Go to: http://www.intel.com/products/processor_number.
3 No computer system can provide absolute security under all conditions. Built-in security features available on select Intel® Solid State Drives may require additional software, hardware, services and/or an Internet connection. Results may vary depending upon configuration. Consult your system manufacturer for more details.
4 Ultrabook is a trademark of Intel Corporation in the U.S. and/or other countries.