Volume: 13 Issue: 06 Pages: 5220-5228(2022) ISSN: 0975-0290

Business Intelligence (BI) Significant Role in Electronic Health Records - Cancer Surgeries Prediction: Case Study

Amira Hassan Abed
Department of Information Systems center
Egyptian Organization for Standardization & Quality, Egypt
mirahassan61286@gmail.com
Mona Nasr
Department of Information Systems, Faculty of Computers & Information
Helwan University, Egypt
m.nasr@helwan.edu.eg

ABSTRACT

Medical datasets reflect a great environment as they integrate analyses of structured and unstructured data that holds several benefits for medical sector. With a continues demand for implementing Electronic Health Records (EHRs), there is a relative requirement for utilizing data mining (DM) techniques to find out useful data, unknown patterns and inference rules from data stored in EHRs which help in a real-time decisions making process and prove-based practice for medical providers and experts. Business Intelligence (BI) is a technology able to process the huge data inside EHRs repository for enhancing the quality of medical delivery. DM is data processing techniques that considered a critical part of the BI platform. In this paper, we highlight significance of the BI integration with the EHRs to aid medical providers and professionals in real- time detection and prediction for several diseases. For more explanation, we apply BI technology with support of clustering technique as one of DM methods, for cancer surgeries prediction to prove the power of cooperating BI and EHRs in medical area.

Keywords**: Business Intelligence (BI), Electronic Health Records, data mining, Cancer Surgeries prediction**

Date of Submission: Apr 13, 2022 Date of Acceptance: Jun 04, 2022

I. INTRODUCTION

The Business Intelligence (BI) has gained great concerns from medical providers, consultations and medical information technology experts for its beneficial in "Electronic Health Records (EHRs)". As stated by Bhatnagar [1], Business Intelligence (BI) simply defined as "the tools an organization uses to gain a greater understanding of operations, markets, and competition". In other words, BI refers to a "collective" term for simply describing data analytics approaches. [2, 3] the "Business intelligence BI tools" are considered a wide range of approaches, technologies, and software to especially gather, maintain, handle, and allow enter onto available data for aid decision makers and top management in taking perfect and swift decisions. [4, 5] BI has developed to be a technology which owns the capabilities for processing the EHRs' "repository content" in order to provide evidence helping medical providers and to enhance the clinical delivery quality. [6]

The reality that the EHRs involve huge medical datasets holds patients' data indicate an important repository for implementing Business Intelligence technology, and so, enhancing the "logic" and "inference" rules resulting from the EHRs.[7] Medical providers and experts gain many benefits from the BI utilization, as these tools ensure wide expects in facilitating the EHRs development as well as introducing enough principles for decision-makers through participating Medical providers and experts [8]. The BI technology abilities make it a power to be integrated when setting up the EHRs' systems standards.

BI owns a number of tools and technologies, involving "an Extraction, Transformation and Loading 'ETL' system", "data warehouse technology", "database query and reporting tools", "Online Analytical Processing System", "data mining techniques" and "data visualization tools". [5] Business Intelligence and Data mining techniques have a significant importance in various areas. The medical and the healthcare sectors are utilizing Business Intelligence tools and Data mining techniques for recording, storing and handling "the Patient Electronic Health Record". As, they also conduct another functions such as "query and reporting", "online analytical processing 'OLAP' ", and "statistical analysis".

In this study, the data were extracted from "the electronic health individual's records" as a source of "patient medical records" and "health status records", after that go to the "data warehouse repositories" then the data were processed using data mining modeling for discovering significant patterns and relationships in the supported datasets (records). For optimizing the results, it would be presented via "the business intelligence visualization tools", for helping end-users in taking perfect decisions.

Volume: 13 Issue: 06 Pages: 5220-5228(2022) ISSN: 0975-0290

II. BUSINESS INTELLIGENCE (BI)

BI receives many concerns in the areas of "data mining" and "knowledge discovery from databases (KDD)". The power of BI technology based on providing advanced technologies to processing data warehouses, thus, introducing strategic business logic to help the decision-makers of organizations. BI is considered as a significant product within information technology field because there is a shortage of data mining tools to be applied with "unstructured datasets". [2] The BI is able to deal successfully enough with structured and unstructured datasets [1]. The data involved in huge datasets can either be structured, unstructured or even semi-structured, and is also be accessed on daily basis from organizations and distinct users, thus there is an extensive role played via BI technologies. [9]

The Business intelligence definition varies from point of views between many academics and authors. BI system is defined according to [10], as "an integrated set of tools, technologies and programmed products that are used to collect, integrate, analyze and make data available". [10] Also, BI tools may define as "A technology that efficiently supports the business operation by providing an interesting value to the enterprise-wide information and thus the way this information is used." [3] Business intelligence get its importance for its ability to discover significant insights based on multi exporter of datasets to finally take a role on informing perfect decisions towards the key organization's goal to be achieved in efficient and effective manners. Also, BI is supported as a mechanism to guarantee advanced methods for managing healthcare data successfully in parallel to ensure "a continuous quality improvement" and "cost control". [11] A number of the key distinctive features that have defined within wide range of studies talks about BI topic are: gathering data from multiple potential heterogeneous sources of data, implement sophisticated data analytical models, and aid multi-users on gaining valuable insights. [4]

III. DATA MINING (DM)

DM is considered one of cutting-edge tools of business intelligence for success "knowledge discovery". The DM analyzing power based on the fundamental of "pattern recognition", "machine learning", and "statistics", as they allows DM to automatically extract knowledge and find extensive patterns from huge datasets. [11] There is the wide range of DM techniques and much advanced variety of methodologies. [12] DM owns a number of advanced and sophisticated data analyzing methods for uncovering interested unobserved and hideaway "patterns and relationships" in huge assets of datasets. These advanced and sophisticated data analyzing methods as common were categorized into "mathematical algorithms", "statistical methods", and "learning algorithms".

Today, various DM tools are available on the market such as "Waikato Environment for Knowledge Analysis 'WEKA'", "Konstanz Information Miner 'KNIME'", "Rapid Miner", "Orange", ...etc for performing swift data analyzing models as "classification, clustering or association rule" and gain valuable insights and patterns.

The tasks and acts of "Data mining Techniques" could model in two patterns "Predictive" or "Descriptive" scheme. For "the Predictive models"; they resulted on a valuable prediction according to "known and identified" data values taken from obtainable datasets, while "the descriptive models" uncover "patterns or relationships" unobserved and hidden in data assets in comparison to the predictive ones, they are completely different.

The "Predictive data mining models" familiar examples are "classification", "prediction", "regression" and "time series analysis". Classification is the well-known "conventional prediction technique" comparing to another data mining methods of "the machine learning". It's main function to classify every object in group of data into one or more predefined group of classes via one of an appropriate classification method such as Decision trees that considered the most common one. [13, 14& 15]

While, for the "Descriptive models" which look for the attributes of the learned data, not focus on predicting any hidden attributes. There are many Descriptive data mining methods like, "Clustering", "Association Rules", "Summarizations", and "Sequence pattern analysis". "Descriptive methods" is built basically to generate "frequency and Sequence", "cross tabulate" and interesting "correlation". Also, it aid to uncover concern unknown symmetry within data, to find out hideaway insights and to uncover concern number of subclasses in the obtainable sources of data. The "Clustering techniques" is the widespread technique for finding out clusters of objects, in which the objects in every cluster are identical to each other.

IV. ELECTRONIC HEALTH RECORDS

According to "the Health Information Management Systems Society's (HIMSS)", it defined "The Electronic Health Records (EHRs)" as "a longitudinal electronic record of patient health information generated by one or more encounters in any care delivery setting including patient demographics, progress notes, and medication, past medical history, immunizations, laboratory data and radiology reports". Electronic Health Record (EHR) is a "repository of information regarding the health status of a subject of care in computer processable form, stored and transmitted securely, and accessible by multiple authorized users" [16]. This definition of the EHR ensures three main elements of the EHR: "repository", "secure storage and exchange of medical information", and "authorized accessibility", which they considered very critical when adopting the EHR in clinical operations. EHR owns abilities to offer "caregivers with all relevant information about every patient"; "encourage the sharing of medical knowledge through computer-assisted clinical decision support"; "facilitate computerized order entry among providers for tests, medicine, and procedures"; and "ensure secure, private, interoperable exchange of health information" between medical providers". [17] the reality that the medical organizations that work through a dynamic environment, Watkins et al. [18] stated that "the standardization of healthcare data using interoperable healthcare information systems such as the EHR will

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provide the foundation for future research and the increasingly vital quality and regulatory reporting".

The EHRs capable of supporting a complete record of clinical patient encounter, as well as supporting other care-related activities directly or indirectly via interface including evidence based decision support, quality management, and outcomes reporting. The electronic health record has been suggested in the seventh decade of the previous century and received great interest from all the Medical organizations. And it symbolizes like an electronic storehouse involving every medical data related to the patient. The EHR have been indicated as the Medical Informatics center which owns the abilities to improving the safety of patient, productivity performance and retrievaling of patient data. While the implementation rate of EHR is still limited at this time, EHR will turn into the focal centric of every patient encounters. The heterogeneous resources of patient data which are currently "standalone systems" will be integrated with the EHRs.

Steve Balmer, the "CEO of Microsoft" stated that, "there will be an "Explosion of Data" as a result of automating and digitizing multiple medical processes. Adding new technologies such as electronic prescribing and regional health information organizations will produce data that heretofore has not been available". [19, 20] A computer-based patient record system is system stored patient information as a tool that able to be easy accessed from "any location" by "any provider" support medical service for patient. [21] The fields and attributes of EHRs involving: "patient demographics", "medical history", "examination of progress reports", "medicine and allergy lists", "appointment scheduling", "retrieval, and archiving of laboratory tests", "graphic image display", "medication ordering (patient safety functions)", "clinical practice guidelines", and "claims and payment processing". The implementation of the EHRs would eventually be regarded to enhance patient health and care status such "morbidity and mortality" like many kinds of "decision support tools" which positively reduce medication errors and standardize care via embedded clinical guidelines.

I. ELECTRONIC HEALTH RECORDS APPLICATIONS

- **Computerized Physician Order Entry**

A demand for the EHRs is the application known as "computerized physician order entry" or "CPOE". "CPOE" is defined by "Electronic Health Records Overview" as "an application used by physicians to order laboratory, pharmacy, radiology services, and other physician orders". [22] CPOE has many significant benefits to medical providers through supporting physicians to order tests electronically without needing for writing orders on medical forms. This improves orders accuracy and informs the appropriate relative area about the arriving of patient.

- **Laboratory Systems**

Almost laboratories in medical sector utilize "lab information systems (LISs)" that integrated with the EHR for organize patient information including examination results. Most of the analyzers working in the labs addition to equipment for conducts tests are involved into these LISs. Also, they contain "lab orders", "lab results", "schedules", and many administration operations.

- **Clinical Documentation**

Medical documents are considered the large HER component, as providers, nurses, and many Medical experts document a huge information amounts related to patient. The patient information is about for example "clinical note's clinical reports", "assessments", and "medication administration records (MAR)".

V. BUSINESS INTELLIGENCE APPLICABILITY IN CANCER SURGERIES (CASE STUDY)

Business Intelligence has developed to be a technology approach owns the advanced capabilities for processing and handling the high numbers of records stored inside EHRs repository. These capabilities offer evidence for enhancing practice and improve the quality of healthcare services. Thus, incorporation of the BI technology with the EHRs has a great role for improving the quality and safety of medical delivery and healthcare services. [1]

Medical datasets provides an excellent environment as they integrated analyses of both "structured" and "unstructured" datasets can prove their importance [3]. Applicability of BI technologies on Medical datasets offers wide range of benefits including the quality improvement and healthcare delivery optimization. Medical datasets are usually unstructured and applying BI tools for ensuring quality data extracting and analyzing.

In the bioinformatics context, BI is realized as so beneficial and is considered as one of the novel data mining frontier. [23, 24] Also, with an increasing concerns and demands for implementing Electronic Health Records, there is a relative need for utilizing data mining techniques to find out significant insights and rules unknown and hidden in the Health and Medical electronic records.

As, Data mining is "the computational procedure of discovering valuable knowledge from extensive data sets including strategies at the crossing point of machine learning and databases technology."[25,26] ML can discover patterns and built algorithms using huge datasets then quantify the information to prepare it for analyzing and prediction tasks. [27, 28] Data mining support real-time data and evidence which help clinicians, and healthcare providers for making perfect decisions. [29]

Cluster analysis has widely been utilized in various applications such as "business intelligence", "image pattern recognition", "Web search", "biology", and "security". In business intelligence, clustering process can effectively manage a huge dataset involved large numbers of objects (cancer Surgeries objects) in groups, where

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cancer surgeries within each group share strong similar features. This facilitates the development of cancer Surgeries strategies for enhancing cancer diagnosis. Moreover, consider a hospital with a large number of cancer Surgeries. To improve cancer Surgeries management, clustering can be applied to partition cancer Surgeries into categories based on similarity so that cancer Surgeries diagnosis can be performed effectively.

Cancer is the name that was given to a set of related disease. There are about more than 200 kind of cancer. Cancer is a disease of the cells that consider the human body's essential "building blocks". The body significantly generates new cells aiming for growing human body, and also for superseding "worn-out tissue" and "healing injuries". Basically, cells double and die through an organized path. Often, cells are not able to develop, divide and die in the usual manner. This may lead to "lymph fluid" in the body to become abnormal, or compose a lump named after a "tumour". A tumour can be benign or malignant.

- **Benign tumour:** cells are just restricted to specific location inside a patient's body and have not ability for prevalence to another site or organ in a patient's body. In that case, it not considered a cancer.
- **Malignant tumour:** it caused by "cancerous cells", which able to prevalence by transporting through the blood streams or "lymphatic system" (lymph fluid).

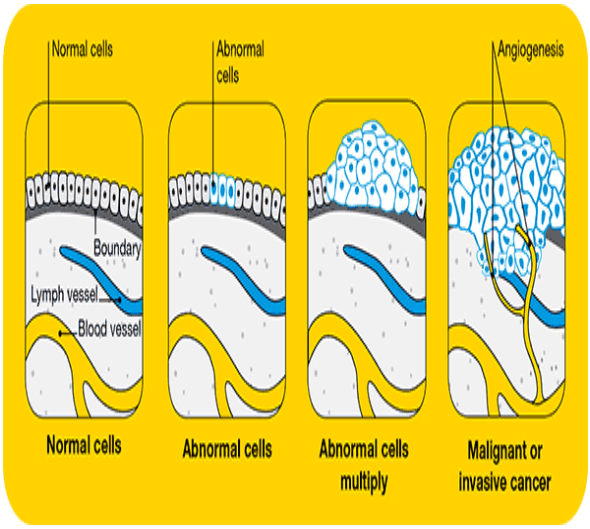

Figure 1: How cancer starts

The cancer that first caused in an organ or tissue is known as "the primary cancer". A "malignant tumour" is commonly called the organ or kind of cell impacted. A "malignant tumour" which does not **spread to other** sites in a patients' body is named after "localized cancer". A tumour may **invade deeper into surrounding tissue** also it able to **grow its own** "blood vessels". In case of the "cancerous cells" increase and develop tumour in another place, it known as a "secondary cancer or metastasis". A "metastasis" remains the original cancer name. For example, "bowel cancer" which has propagated for a "liver" is known as the "metastatic bowel cancer", although a patient can be suffering symptoms happen according to the critical liver problems.

Cancer surgeries eliminate the tumor and close tissue through performing an operation by a surgical oncologist. Surgery considers the oldest "cancer treatment", also it regard as effective solution for various kinds of cancer all over the world. We can mention various reasons why patient have to perform cancer surgery:

1. Diagnosing cancer exactly.
2. Removing whale or only part of cancer.
3. Determine a location of a cancer inside a patient body.
4. Determine if the cancer has spread or it has impacted on other organs' functions.
5. Restoring the body's functions.
6. relieving side effects

Determining the surgery type for treating cancer is based mainly on the cancer area and degree/ stage and patient's general health. We list a number of the most well known cancer surgery types, as supported in **Table 1**.

Case Study: Cancer Surgeries in California Hospitals

In this study, we attempt to investigate the Cancer Surgeries volume by Applying business intelligence technologies. In 2021, California Office of Statewide Health Planning and Development (OSHPD) aimed for Calculating the Volume of Cancer Surgeries performed in California Hospitals. In this respect, they utilized and analyzed "The Cancer Surgeries (Volume) Performed in California Hospitals dataset", which was produced by the Healthcare Information Division staff. The dataset contains the number (volume) for 11 types of cancer (bladder, breast, brain, colon, esophagus, liver, lung, pancreas, prostate, rectum, and stomach) surgeries performed in California hospitals. Also, it contains 11,822 entries or objects and 9 attributes, as shown in **table 2.**

Table 1: The common cancer surgery types

Surgery	Cancer type
Colectomy	Bowel
Craniotomy	Brain
Cystectomy	Bladder
Gastrectomy	Stomach
Hepatectomy	Liver
Hysterectomy	Cervical, ovarian, uterine
Laryngectomy	Laryngeal (voice box)
Lobectomy	Lung
Mastectomy	Breast
Nephrectomy	Kidney
Oesophagectomy	Oesophageal
Orchidectomy	Testicular
Pancreaticoduodenectomy (Whipple's procedure)	Pancreatic
Pneumonectomy	Lung
Prostatectomy	Prostate

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According to, the richness and importance of this dataset, there is an exactly need for conducting cluster analysis on this dataset for discovering meaningful information which facilitate real-time decisions, improve patient diagnosis, and support evidence-based practice.

Data are gathered from January 2016 till September 2021 according to ICD-9-codes then the coding had changes to ICD-10-CM/PCS for procedures, which started 10/1/2018 till the end of 2021. The ICD-9-codes & ICD -10 codes were reviewed by professionals and experts for ensuring the success of coding process in which each code is correlated to specific cancer-directed surgeries. Also, they were tested for determined every code is exactly reflect the interested "malignancies". OSHPD data were utilized for ensuring that specific ICD-9 and ICD-10 as the "procedure codes" didn't miss. First, they selected ICD-9-codes or ICD -10 codes detection codes for the interested "malignancies". Frequencies of the well known ICD-9-codes or ICD -10 codes procedure codes related to these detection were after that run for ensuring that ICD-9-codes or ICD -10 procedure codes for each cancer type was involved in its list.

Concerned patients in our analyzing mission were discharged from “California -licensed general acute care hospitals” in our scope years and had the ICD-9 or ICD-10 site-specific cancer diagnosis and the ICD-9 or ICD- 10 procedure code(s) related to specific cancer type. Patients were excluded in case of they “were less than 18 years of age”; “were in long-term acute care”, “hospice care, or pediatric facilities”. Volume counts were evaluated according to a patient discharge, so patient may be appeared many times in case of he/she was admitted to hospital on different dates for the “same surgery” and the “same diagnosis”. But, follow-up analyzing processes ensure that this rarely not caused for all cancer surgeries in our scope.

CLUSTERING K-MEANS ALGORITHM

Basically, the real world databases may contain a “noisy”, “missing”, and “inconsistent” data which can cause for different reasons such as the data size is huge and being gathered from multi sources [11]. In this respect, the Data quality concept get a great role to be an impacted success factor in which influencing positively on various analyzing purposes such as cancer diagnosis and prediction, as low quality data can seriously find out inaccurate prediction outputs. In this work, for making sure that the selected dataset not contains “noisy”, “missing”, and “inconsistent” data to be prepared for clustering and predicting cancer surgeries, we applied advance preprocessing methods using “weka” professional package that supported for performing complicated analysis tasks. Data preprocessing do a set of processes, including: cleaning, editing, normalization, transformation, and attribute selection. After all these processes, we will have the final “**training set”**.

When we perform the preprocessing phase on our dataset, the missed values had detected in four attributes (Country, OSHPDID, Latitude & Longitude attribute). The Country and OSHPDID attributes missed values for 66 instances/objects of the given dataset, and the Latitude and Longitude attributes missed values for 73 instances. As a result, the "Filtering Capabilities" were utilized for handling these issues for preparing the given dataset to be applicable for the clustering task. From the Filtering Capabilities, the "missing values capability" was used for identifying the instances that missed values then edit the "missed values" with a "customized value", which we informed for handling these issues.

Actually, our main aim was to cluster the given data (the selected dataset) for grouping the most similar instances in clusters a way that objects/instances in the same cluster are more similar to each other than “objects in other clusters”. In other words, we attempted to find out "the structure of the data" through grouping the data instances into distinct clusters (subgroups). K-means algorithm is an "iterative algorithm" is capable for partitioning the dataset into distinct non-overlapping subgroups where each data object belongs to just one cluster/group. As shown, we performed clustering task based on the given dataset using simpleK-means algorithm as shown in figures 2 & 3. The clustering resulted in two clusters through five iteration taking 0.33 second to build the clustering model.

VI. CONCLUSION

This work tries to explore the importance of the BI technology integration with the EHRs. The work can guide medical providers and stakeholders in indentifying the BI technology applicability in “healthcare and medical” information systems.

As many problems may cause during the implementation of BI application in medical practice, however the BI systems become more widespread and smart as many organizations invest in the integration of BI with medical records management projects. Medical providers have to consider the BI platforms as an investment solutions subject to maximize several medical operations. Many authors mentioned that it is “difficult to find a successful enterprise that has not leveraged BI technology for their business”. Thus, the medical and information technology providers and vendors have to be aware of the importance and power of data maintained inside the EHRs and obtain BI technology benefits to support them in the “knowledge discovery” process. The BI systems also support as an “E-discovery” platform helping medical providers in evaluate the potential data of both “structured” and “unstructured” datasets stored within the EHR repository.

The increasing applicability of BI technology requires additional research to find out the appropriate utilization in the medical sector. Additional research and implementation of the BI technology have to discover the gap between experts, academia, authors and providers through identifying the critical success factors that impact positively on implementation of BI solutions in medical information systems.

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Table 2: Dataset's attributes & its values

Attributes	Possible values
Year	{2016, 2017, 2018, 2019 , 2020 , 2021}
county	{Alameda, Butte, Calaveras, Colusa, Contra Costa, Del Norte, El Dorado , Fresno , Humboldt ,Imperial, Inyo, Kern, Los Angeles, Stanislaus}
Hospital`	{Statewide, Alameda Hospital , Alta Bates Summit Medical Center – Alta Bates Campus, Highland Hospital, Kaiser Foundation Hospital – Oakland Campus, Alta Bates Summit Medical Center – Summit Campus – Hawthorne, Saint Rose Hospital, Washington Hospital – Fremont, San Leandro Hospital, Valleycare Medical Center, Eden Medical Center, Sutter Amador Hospital, Feather River Hospital}
OSHPDID	{1.06E+08, 1.07E+08}
Surgery	{Colon, brain, Bladder, Breast, Lung , Prostate, Rectum, Stomach, Liver, Pancreas, Esophagus }
Number of Cases (ICD 9)	{minimum number =1 , maximum number = 25829}
Number of Cases (ICD 10)	{minimum number =1 , maximum number = 29349}
Latitude	{37.76295, 37.85633 , 37.79917 , 37.82425 , 37.62593 , 37.82106 , 37.63291, 37.55847,37.71364,37.69206 , 40.90351 , 39.13881}
Longitude	{-122.254 , -122.258 , -122.231 , -122.093 , -122.09 , -121.98 , -122.141 ,-121.881, -122.087 , -121.691, -121.572 , -121.543 , -121.849 , -122.339 , -122.131, -121.805 , -117.157 , -117.471 , -117.181, -117.185 , -117.195 , -121.594}

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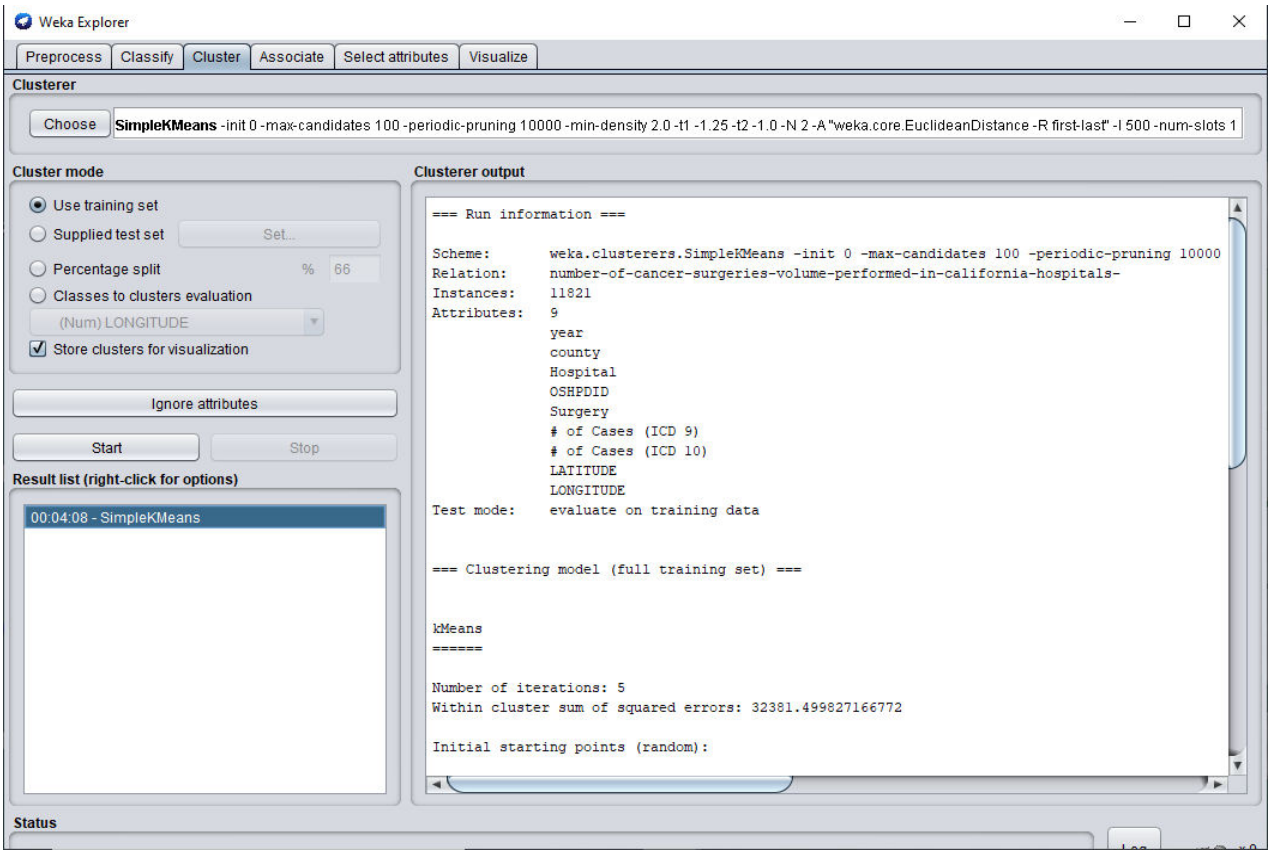

Figure 2: The cluster analysis for cancer surgeries in California hospitals using simple K-means algorithm

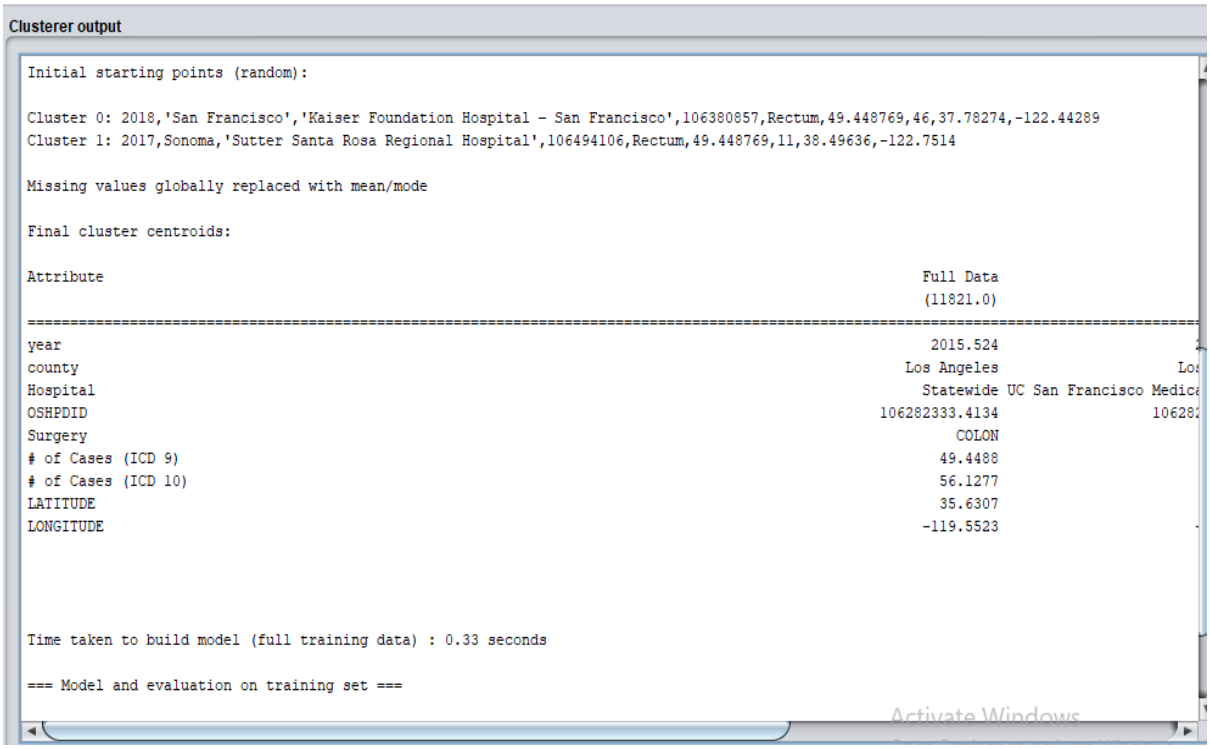

Figure 3: cont. the cluster analysis for cancer surgeries in California hospitals using simple K-means algorithm

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