FogLearn: Leveraging Fog-based Machine Learning for Smart System Big Data Analytics

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ABSTRACT

Big data analytics with the cloud computing are one of the emerging area for processing and analytics. Fog computing is the paradigm where fog devices help to reduce latency and increase throughput for assisting at the edge of the client. This paper discussed the emergence of fog computing for mining analytics in big data from geospatial and medical health applications. This paper proposed and developed fog computing based framework i.e. FogLearn for application of K-means clustering in Ganga River Basin Management and real-world feature data for detecting diabetes patients suffering from diabetes mellitus. Proposed architecture employed machine learning on deep learning framework for analysis of pathological feature data that obtained from smart watches worn by the patients with diabetes and geographical parameters of River Ganga basin geospatial database. The results showed that fog computing hold an immense promise for analysis of medical and geospatial big data.

Keywords. Cloud Computing, fog computing, medical big data, geospatial big data, visualization, river, diabetes, geospatial data, k-means, clustering

INTRODUCTION

Cloud computing has provided for exchange and sharing of data belonging to various stakeholders. This emerging computing has created a robust framework that enabled wide variety of users to retrieve and access geospatial data along with associated metadata in a secured manner (Brovelli et al., 2016a; Chen et al., 2012). It has leveraged for land use and urban planning, natural resources management, environmental assessment monitoring marine and tele healthcare monitoring. There are numerous emerging applications of cloud computing in geospatial and health application. It has the ability to integrate and analyze heterogeneous thematic layers along with their attribute information to create and visualize alternative planning scenarios (Brovelli et al., 2016b) in geospatial scenario. It has integrated widespread geospatial database operations with variety of queries formations, different overlay analysis, and numerous statistical computations with unique visualization functionalities. These types of features have distinguished the cloud computing based framework from other geospatial decision support systems. This framework has widely used tool in private and public sectors for predicting outcomes, illumination events, manipulating and designing strategies (Brovelli et al., 2014; Barik. and Samaddar, 2014b; Coleman et al., 2016; Georis-Creuseveau et al., 2016).

Geospatial data contains geospatial distributions and informative temporal data. In traditional setup of cloud computing based GIS framework, it sends data to cloud server where these are processed and analyzed (Huang et al., 2013; Yang et al., 2011; Yang, et al., 2017). This scheme has taken for large processing time and required high Internet bandwidth. Fog computing overcomes this problem by providing local computation near the edge of the clients. Fog computing enhances the Cloud computing based GIS framework by reducing latency at increased throughput. Fog devices such as Intel Edition and Raspberry Pi has provided low-power gateway that can broaden the throughput and reduces the latency period near the edge of geospatial/end user clients (Barik et al., 2016; Dubey et al., 2017; Yang et al., 2010). In addition, it reduces the cloud storage for geospatial big data. Also, the required transmission power needed to send the data to cloud is reduced as now we send the analysis results to cloud rather than data. This leads to improvement in overall efficiency. Fog devices can act as a gateway between clients such as mobile phones and wearable sensor devices. The increasing use of smart devices led to generation of huge geospatial big data. Cloud and fog services leverage these data for assisting different analysis. It suggests that the use of low-resource machine learning on Fog devices which kept close to smart devices. For traditional systems, the different processing and machine learning modules are deployed in cloud that process physiological data.
The increasing use of wearable in smart tele-health system led to generation of huge medical big data. Cloud and fog services leverage these data for assisting clinical procedures. IoT Healthcare has been benefited from this large pool of generated data. It suggests that the use of low-resource machine learning on Fog devices which kept close to wearable devices for smart tele-health. For traditional telecare systems, the signal processing and machine learning modules are deployed in cloud that process physiological data. The present research paper also illustrates on unsupervised machine learning big data analysis for discovering patterns in physiological data in fog environment.

So, both geospatial and medical data are processed at the edge using of fog devices and finally has stored at the cloud layer. The present research paper has made the following contributions:

- It describes the detail concepts and architectural framework about the edge, cloud and fog computing;
- It presents the big data concept in the field of geospatial and medical applications with some machine learning techniques in fog computing environments;
- It discusses about proposed architecture of FogLearn framework that leads to process the various geospatial and medical big data analytics at the edge computing environment;
- There are two case studies i.e. River Ganga basin management and diagnosing patients with diabetes mellitus; have been elaborated with the use of different fog assisted cloud architecture.

RELATED AND BACKGROUND STUDIES

**Edge Computing**

Data are gradually produced and processed at the edge of the network. Same works have done before in micro data center and cloudlet as cloud computing is not always capable enough for data processing when the data are volumetric produced at the edge of the network. Edge computing allows more edge devices or sensors to interface with the cloud in larger scale. Since the cloud computing environments are not setup for the volume, variety and velocity of data. It has changed the systems before the cloud must be adapted to improved make use of the cloud services accessible (Dey and Mukherjee, 2016). In the edge computing concept, the things not only are data producers, but also play as data consumers. At the edge, the nodes perform the computing tasks from the cloud as well as request service and content from the cloud. Edge computing can perform data storage, offloading, computing, distribute request and delivery service, caching and processing from the cloud layer to client tier layer (Dastjerdi et al., 2016; Chiang and Zhang, 2016; Senaratne et al., 2017). With the verity of jobs in the edge network, the edge nodes need to be well calculated to gather the prerequisite efficiently in security, privacy protection and reliability service. In edge computing, it has required to set the computing at the proximity of different data sources. There are great benefits as compare to the traditional cloud computing paradigm. For example, various smart mobiles are the gateway in the smart homes are the edge between home things and the cloud, the edge between body things and the cloud layer, micro data centers and cloudlets are the edge between the mobile devices and the cloud layer. The underlying principle of edge computing is that the computing happens at the closeness of data sources. From these point of view, edge computing is negotiable with fog computing, but edge computing has more focused towards the things side, while fog computing is more focus on the infrastructure side.

**Cloud Computing**

Cloud computing provides the shared resources and on-demand facilities over the cyberspace. It possesses numerous computational infrastructure and adequate storage for data visualization and analysis. Cloud computing provided a transition from desktop to cloud servers. Various web processing architectures have created in an open environment with shared assets. It was facilitated by four distinct types of service model, i.e., Database as a Service (DaaS), Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). These four different types of service models are depicted in Fig.1.
IaaS model includes Virtual Machines (VM) and storage area for storing of data. Load balancing in cloud computing is performed using IaaS. End-users can install or access the desired software through VMs. IaaS model offered hardware platform to the end users on-demand basis. This way the end users have online access to hardware platform as per their needs. PaaS is responsible for the development and delivery of programming models. Users can access PaaS through cloud computing framework. It facilitates execution of required programs. PaaS service model completes the needs of building and delivering web applications without installing or downloading the required software. SaaS model deals with different applications. SaaS services could be accessed through web browsers. SaaS service model allows software deployment in a way that users could run applications without installing those on their system. However, this model is limited to a set of services. A more flexible model, DaaS provide its users access to a database without software installation or hardware setup or configuration. All of the administrative and maintenance tasks are handled by the service providers. Customers can have control over the database depending on the service providers. All the above discussed models were used for various application areas. Particularly SaaS and DaaS model are dedicated for geospatial applications. Analysis and storage of geospatial data requires a robust framework. Such system works on top of PaaS service model in Geospatial cloud computing framework (Yang et al., 2010; Huang et al., 2013; Patra and Barik, 2015). It is one of the unique platform which is using the interrelates with tools, technologies and expertise to nurture needs for handling, using and producing different types geospatial and statistical data.

It has been deployed multi-tenant design and unique instance that permits different clients to add assets without disturbing to each other. This integration of hosted services method has helped for installing application advancements for the transparency of user. Another characteristic is embrace of geospatial web services and as an established architectural methodology in engineering. Cloud platforms are also uncovered functionalities and applications statistics via geospatial web services. These permit clients to query or update different types of cloud applications and service. It is a tool that assimilate software cloud with enterprise SOA infrastructure (Barik and Samaddar, 2014a; Barik and Samaddar, 2014b). Fig. 2 shows the system architecture for Geospatial cloud computing framework.
Figure 2. System architecture of Geospatial cloud computing framework with thick, thin and mobile clients. It has client-tier layer, application-tier layer divided into different web services and data-tier layer with geospatial and meta-data storage.

The client tier layer consists of three types of clients i.e. thin, thick and mobile clients. These three types of clients have the main function to visualization functionality for geospatial data. Mobile client is the user which operating through the mobile device or PDA. The user is working on the web browser is known as thin clients where user does not require any extra software for the operation. Thick client is the user where visualizing or processing the geospatial data in standalone system. Thick client users require extra plug-in/software for operation of different applications (Barik et al., 2014a). Different geospatial services are executed by the servers in application tier layer. It is act as the middle tier amongst the different clients and the service providers. Various servers for every application have operated for services i.e. Web Coverage Service (WCS), Web Map Service (WMS), Web Feature Service (WFS), Web Catalog Service (CSW) and Web Processing Service (WPS) (Evangelidis et al., 2014; Wang, et al., 2015).

Application servers are responsible for requests to and from the clients. In addition, several services have included the three types of applications i.e. data servers, catalog, and processing servers. Several catalog servers are employed to search the metadata regarding the stored geospatial data. It is an important component for controlling geospatial information in cloud computing environments. The catalog services have implementation of a standard publish-find-bind model. This model is defined by OGC web service architecture. Data server deals with the WCS, WMS and WFS. Different types of processing servers offer numerous geospatial data processes which allow different clients to smear in WPS standard geospatial data. Detail explanation of every processes have done by the client request which forwarded to the desire processing service, provides and specifies the definite region and feedbacks with the different composite standards. The data tier layer has the geospatial data along with different information. Systems utilize the data tier layer to recover, store, update and manipulate the geospatial data for analysis. Data have stored in different open source packages or simple file system. The system architecture of Geospatial cloud computing shows that geospatial data are one of the key components in data layer for the handling geospatial analysis. The widespread use of cloud for geospatial data storage and analysis lead to generation of large amount of data from different areas (Fiduccia et al., 2016; Delipetrev et al., 2014).

**Fog Computing**
Cloud computing paradigm has the limitation as most of the cloud data centers are geographically centralized. These data centers are not located near the proximity of users or devices (Barik et al., 2016; Dubey et al., 2017). Consequently, latency-sensitive and real-time computation service requests by the distant cloud data centers has often suffer large network congestion, round trip delay and degraded service quality. Edge computing is an emerging technology for resolving these issues. Edge computing provides the computation nodes near the edge, i.e., close to the clients. It enables the desired data processing at the edge network that consists of edge devices, end devices and edge server. Devices are the smart objects, mobile phones whereas routers, bridges, wireless access points are the employed as edge servers. These components function co-operatively for supporting the capability of edge computation. This paradigm ensures fast response to computational demands and after computation; the analysis report could be transferred to cloud backend. Edge computing is not associated with any kind of cloud services model and communicate more often with end devices. Various combinations of edge and cloud computing lead to emergence of several computational paradigm such as mobile cloud computing (MCC), mobile edge computing (MEC) and fog computing (Dastjerdi et al., 2016; Barik al., 2017; Sareen et al., 2017).

Fog computing has first coined by Cisco in 2012. It is a computing paradigm that decentralizes the resources in data centers towards the different users for improving the Quality of Service (QoS) and experience. This computing do not require computational resources from cloud data centers. In this way, data storage and computation are brought closer to the users leading to reduced latencies as compared to communication overheads with remote cloud servers. It refers to a computing paradigm that uses interface kept close to the devices that acquire data. It introduces the facility of local processing leading to reduction in data size, lower latency, high throughput and thus power efficient systems. Fog computing has successfully applied in smart cities and healthcare (Dubey et al., 2017; Dubey et al., 2015; Sareen et al., 2016).

Fog devices are embedded computers such as Intel Edison and Raspberry Pi that acts a gateway between cloud and mobile clients. From the above discussions, we can see that it requires an efficient, reliable and scalable Fog computing based GIS framework for sharing and analysis of geospatial and medical big data across the web. Fog computing is a novel idea that helps to reduce latency and increase throughput at the edge of the client with respect to cloud computing environment (Barik et al., 2017; Hossain et al., 2017; Bhatia and Sood, 2017). Fog computing solves the problem by keeping the data closer to local devices and computers, rather than routing through a central data center in the cloud. The simple fog computing architecture has shown in Fig. 3.

Figure 3. Fog computing is as an intermediate layer between edge computing layer and cloud layer. The Fog computer layer has enhanced the efficiency by providing computing near the edge computing devices. This framework is very much useful for geospatial application, healthcare, smart city, smart grid and smart home etc. (Barik et al., 2016).

Geospatial and Medical Big data
Big data have distribution, scale, timeliness and diversity. It requires the analytics to enable insights and the use of new technical architectures that unlock new variety resources of different business value. It includes large data sets whose sizes is beyond the ability of commonly used software tools. It requires special tools to acquire, curate, manage, and process big data in realistic time frames. Big data is generated in multiple forms. Most of the big data is semi-structured, quasi-structured or unstructured, that makes the processing challenging. Appropriate analysis of big data can discover new correlations to spot business trends, combat crime, and prevent diseases. Big datasets are growing rapidly because they are increasingly gathered by economical and numerous radio-frequency identification (RFID) readers, microphones, aerial (remote sensing), cameras, information sensing mobile devices, wireless sensor networks and software logs. Geospatial data has always big data with the combination of remote sensing, GIS and GPS data. In these days, big data analytics for geospatial systems is receiving attention. Geospatial big data usually refer to spatial data sets beyond the capacity of traditional computing infrastructures (Barik et al., 2016; Dubey et al., 2015).

Geospatial data are categorized into raster, vector and graph data. Raster include geospatial images obtained from satellites, security cameras and aerial vehicles. The raster data are utilized by government agencies for analysis, prediction and decision making. Feature extraction, change detection and pattern mining are some examples of analyzing raster data. Vector consist of points, lines and polygons features. For example, in Google maps, the various temples, bus stops and churches are marked with points data whereas lines and polygons correspond to the road networks. Spatial correction, pattern analysis and hot spot detection is usually done using vector data. Graph appears in form of road networks. Here, an edge represents a road segment and a node denotes an intersection or a landmark(Barik et al., 2017; Andreu-Perez et al., 2015).

Due to diversity of health-related ailments and variety of treatments and outcomes in health sector, there are numerous health care data have generated. That gives rise to the concept of medical big data. Electronic health records, biometric data, clinical registries, medical imaging, patient-reported data and different administrative claim record are the main sources for medical big data. Medical big data have several typical features that are different from big data from other disciplines. These big data are often hard to access and Investigators in the medical area are aware of risks related to data privacy and access (Lee and Yoon, 2017).

Big data poses some challenges for data analysis with cloud computing. Reliability, manageability and low cost are the key factors that make cloud computing useful for data processing. However, the security and privacy are the main concerns for processing sensitive data. Particularly in health geo-informatics applications with sensitive data, we require secure processing. For minimizing privacy and security threats, the data should be utilized as per the user's context for limited amount of data access within the model. After processing, the data should be transferred to the next level for final processing of data analysis. That will benefit the data privacy and security (Lee and Kang, 2015; Ma et al., 2015).

Proposed Fog Architecture: FogLearn

This section describes various components of the proposed architecture i.e. FogLearn and discussed the hardware, software and methods implemented for machine learning approaches on geospatial and medical big data. It employed Intel Edison and Raspberry Pis as fog computing device in proposed framework. Intel Edison is powered by a rechargeable lithium battery and contains dual-threaded 500MHz, dual-core and Intel Atom CPU along with a 100MHz Intel Quark micro controller. It possess 1GB memory with 4GB flash storage and supports IEEE 802.11 a,b,g,n standards. It connects to WIFI and based on UbiLinux operating system for running compression utilities. Fig. 4 has shown the proposed architecture employing fog gateway between client and cloud layer.
The proposed FogLearn framework has three layers as client tier layer, fog computing and cloud computing layer. In client tier layer, the categories of users divided into thick client, thin client and mobile client environments. Processing of geospatial and medical big data can be possible within these three environments. Cloud computing layer is mainly focused on overall storage and analysis of geospatial and medical big data. The fog computing layer worked as middle tier between client tier layer and cloud computing layer. It experimentally validated the fog computing layer as low power consumption, overlay analysis capabilities and reduced storage requirement. In fog computing layer, all fog node developed with Intel Edison processor for processing of geospatial and medical data.

FogLearn framework used to assist and hence enhanced the capabilities of cloud computing framework. The Fog layer in FogLearn processes the data and after processing, it has the ability to send the data to cloud layer for long term analysis and storage. So, this framework enables the more power to the end-users for better performance without computational overhead at cloud layer. The designed framework has the benefit when computational overhead at cloud layer has very high and geospatial data sizes are expanding. Thus, the fog layer increases the overall efficiency by reducing the latency and increasing the throughput. This framework added privacy benefit where we processed the data locally at fog devices and sent only the analysis results to cloud computing layer. In the proposed framework, the number of fog devices has
utilized according to application demand. For example, in case we have large amount of data that has to be processed in short time, we need more fog nodes. In this paper, we used two number of fog devices for analysis and processing. However, the number of devices would not change the architectural advantages.

CASE STUDY I: GANGA RIVER BASIN MANAGEMENT SYSTEM

Ganga River Basin Management: Indian Scenario

Ganga River along with her numerous tributaries have been the source of spiritual and physical sustenance. The physical environment of the Ganga River Basin is governed by a complex combination of natural processes and man-made which has given the rise to environmental dreadful conditions. So for the controlling these types of environment degradations, River Ganga Basin Environment Management Plan (GRBEMP) seeks ways and means to strengthen the basin environment. For planning the recovery of a river Ganga, there are lots of task of analyzing the environment has broken up such as Communication and Geospatial Database Management Thematic Groups, Water Resources Management, Fluvial Geomorphology, Ecology and Biodiversity, Environmental Quality and Pollution, Socio-economic and Socio-Cultural Policy Law and Governance. These eight thematic groups have assisted by Ministry of Environment & Forests of India and seven Indian Institute of Technology (IIT) of India for the development of GRBEMP (Internet-1, 2017; Internet-2, 2017; Satish, 2015; internet-3, 2017).

Therefore, there is a suitable framework which has been designed and implemented to integrate geospatial and temporal information of DEM, land use, administrative boundaries, global soil and weather data related to Ganga river. From the present proposed and developed framework, it has visualized that the well location and dam geospatial databases have stored in shape files. These files has shown in Fig. 5.

Figure 5. Integration of river Ganga basin geospatial database in FogLearn framework.
These files are downloaded and used in our FogLearn framework. The well location geospatial database of Ganga river have utilized for several analyses such as compression, overlay and cluster analysis (internet-4, 2017; internet-5, 2017). The next section has described the machine learning approaches in the developed framework with well location geospatial database with Google Maps and other open data layer services.

**Machine learning approaches in FogLearn**

K-means clustering technique is a type of unsupervised machine learning approach which needs to group similar types of things together. Primarily, it has defined with k centers in the data points to starts, it has been suggested to place these points near to the possible from each other. After that the distance of each point calculated this center and the points that have minimum distance to the center added to that cluster (Gupta and Merchant., 2016). Then, it has taken the mean of cluster points and the mean becomes the new centroid of the given cluster of data. The processes have repeated until clusters are stable. The k-means algorithm is easy to implement and robust. This algorithm has a very wide application and recently it has utilized in many of the geospatial and health application areas like in automatic lane detection. In this case study, K-means algorithm has written in R open source tools.

In the present study, it has taken the well location shape file for river Ganga basin plan. Primarily, the well location geospatial database is stored in the system as shape file format. It has converted the shape file into .csv file format in Quantum GIS desktop environment. The .csv files have used for k-means clustering techniques and are several parameters which are investigated i.e. WellCode, District, WellType and particular location of each well location in .csv file format. It has done with several cases according to the parameters in well location files. Figure 6 (a) has shown the k-means clustering on longitude and latitude where it has divided into 5 clusters. Figure 6 (b) has illustrated the k-means clustering on longitude and latitude where it has visualized according to the state of India where the well has located near the Ganga basin. From Figure 6 (b), it has visualized that there are eight number of state and one union territory of India lies with Ganga. Similarly, Figure 6 (c) has also described the location of well and categorized according to the types of well type. Well type is divided into 4 types i.e. dug well, bore well, piezometric and tube well type. It has observed that the more dug wells are associated with the basin of Ganga.

![Figure 6](https://example.com/image.png)

*Figure 6. (a) five cluster in k-means approach; (b)Cluster in state wise of India; (c) Cluster in WellType related to the Ganga river basin.*
From the above clustering analysis, it experimented that there is required to add additional fog nodes in between fog computing layer to cloud computing layer. So, it requires illustrating the idea of Fog-to-Fog interface for better and efficient management of geospatial data.

CASE STUDY II: PREDICTION OF DIABETES IN TELEMONITORING SYSTEM

Diagnosing patients with Diabetes mellitus

Diagnosing the diabetes mellitus is highly required in tele-health monitoring system. The way of treatment required for a diabetic person is different than a normal person. For detecting whether a person is diabetic or not, the features which are taken in this work are 1) Plasma glucose concentration 2) Diastolic blood pressure 3) 2-Hour serum insulin (mu U/ml) 4) Body mass index 5) Diabetes pedigree function 6) Age (in years). These data can be collected using health sensors embedded smart phones. For experimental purpose, a standard dataset from UCI learning repository (C.L. Blake, C.J. Merz) is taken and used. In this dataset, there are 768 samples present, out of which 600 samples are employed as training and 168 samples are employed for testing purpose (Priyadarshini et al., 2017; Internet-5, 2017).

The proposed model is based on handling medical big data. So, for accomplishing the task of classification, conventional classification tools like neural networks are substituted by deep neural network. The classification of diabetes and non-diabetes people is done by using a simple deep neural network. A deep neural network model is configured using Deeplearning4j tool. Deep learning 4j is java based open source library for creating and deploying deep neural network. These libraries are customized through an Inteli-J idea which is an open source java IDE (Internet-6, 2017). The model is tailored according to the suitability of the current data. The classification accuracy is coming as 81.89%. This measure is taken on an averaged 10 random iterations. Fig.7 has shown the plotting of classification result of training and test data sets.

CONCLUSIONS

In the present research paper, River Ganga Basin geospatial database and diagnosing the diabetes mellitus data from in-home monitoring of patients with diabetes disease were considered for case study using FogLearn architecture. We further leveraged machine learning approaches such as k-means clustering and deep neural network on well-type data from River Ganga Basin geospatial database and diabetes data. In future, it would like to add more intelligent processing procedures. It also validated FogLearn architectures for application-specific case studies. Intel Edison processor and Raspberry Pi were used as fog processors in fog computing layers. Fog nodes not only reduce storage requirements but also results in efficient transmission at improved throughput and latency. Fog of things is collection of all nodes between
client layer and cloud. The edge computing done on fog nodes creates an assistive layer in scalable cloud computing. With increasing use of wearable and internet-connected sensors, enormous amount of data is being generated.

The cloud could be reserved for long-term analysis. Fog computing emphasizes proximity to end-users unlike cloud computing along with local resource pooling, reduction in latency, better quality of service and better user experiences. This paper relied on Fog computer for low-resource machine learning. As a use case, we employed deep neural network to classify and predict diabetes disease on patients with diabetes. Proposed FogLearn architecture is showing around 81% of accuracy in prediction of analysis. Fog computing reduced the onus of dependence on Cloud services with availability of big data. There will be more aspects of this proposed architecture that can be investigated in future. It can expect fog architecture to be crucial in shaping the way big data handling and processing happens in near future.

REFERENCES


