# Big data Visualization with Apache Zeppelin

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**Apache Zeppelin is an open source notebook for data analytics and visualization. In this project Apache Zeppelin is used to deploy and do visual data analytics by taking advantage of parallel computing capabilities of Spark in multiple cloud environments.**



**Keywords:** Zeppelin, Apache, Big data, Visualization

https://github.com/cloudmesh/sp17-i524/blob/master/project/S17-IR-P008/report/report.pdf

## 1. INTRODUCTION

Interactive browser-based notebooks enable data engineers, data analysts and Data scientists to be more productive by developing, organizing, executing, and sharing data code and visualizing results without referring to the command line or needing the cluster details. Notebooks allow these users not only allow to execute but in order to interactively work with long work-flows There are a number of notebooks available with Spark. Although IPython remains a mature choice and great example of a data science notebooks, it has certain limitations when used for visualizations with spark which are fulfilled by Apache Zeppelin.

Apache Zeppelin[1] is a upcoming web-based notebook which brings data exploration, visualization, sharing and collaboration features to Spark. It supports Python and also has a growing list of programming languages such as Scala, Hive, SparkSQL, shell and markdown.

It is a completely open web-based notebook that enables interactive data analytics used for data ingestion, discovery, analytics, visualization and collaboration. It has built in Spark integration and supports multiple language backends like Python, Hadoop HDFS, R etc. Multiple languages can be used within same Zeppelin script and share data between them. In this project we deployed Zeppelin along with in built Spark and backend languages R and Python across cluster using Ansible. Then installed additional visualization packages provided by Apache Zeppelin Helium[2] APIs.

We also loaded a data set into Spark across cluster and perform data analytics and visualization in cloud using Zeppelin. However since the goal of this class project is focus on deployment of Big data software across multiple machines and benchmarking the time for deployments, we focused more on that through out the paper and gave less importance to the analytics that are performed after the deployment.

## 2. INFRASTRUCTURE

The deployment of Apache Zeppelin is done on two clouds. The clouds selected for the purpose of this project are

1. Chameleon Cloud
2. JetStream Cloud

### 2.1. OpenStack

OpenStack[3] is a cloud operating system that controls large pools of compute, storage, and networking resources throughout a data center, all managed through a dashboard that gives administrators control while empowering their users to provision resources through a web interface. It was created as joint project between NASA and Rackspace that is currently managed by OpenStack Foundation. It is open source software released under the Apache 2.0 license.

Both Chameleon cloud and JetStream use OpenStack. OpenStack is a free, open source cloud computing platform primarily deployed as IaaS.[4]

### 2.2. Chameleon Cloud

Chameleon Cloud[5] provides a large-scale platform to the open research community allowing them to explore trans-formative concepts in deeply programmable cloud services, design and core technologies. It is funded by the National Science Foundation. The testbed of Chameleon Cloud is hosted at the University of Chicago and Texas Advanced Computing Center and the University of Chicago. Chameleon provides resources to facilitate research and development in areas such as Infrastructure as a Service, Platform as a Service, and Software as a Service. Chameleon provides both an OpenStack Cloud and Bare Metal High-level Performance Computing Resources[6].

### 2.3. JetStream Cloud

Jetstream is led by the Indiana University Pervasive Technology Institute (PTI), will add cloud-based computation to the national cyberinfrastructure. Researchers will be able to create virtual machines on the remote resource that look and feel like their lab workstation or home machine, but are able to harness thousands of times the computing power. Jetstream will provide the following core capabilities use Virtual Machines interactively, Researchers and students can move data to and from Jetstream using Globus transfer[7], use virtual desktops and publish VMs with a Digital Object Identifier(DOI)[8].

### 2.4. Virtual Machine Specifications

A brief comparison of multiple attributes of the clouds discussed above are shown in the table 1.

| *Clouds* | *Chameleon* | *Jetstream* |
|---|---|---|
| *CPU* | Intel Xeon X5550 | Dual Intel E-2680v3 "Haswell" |
| *RAM* | 4 GB | 2 GB |
| *Number of CPU's* | 1 | 1 |
| *CPU Cores* | 1 | 1 |
| *CPU Speed* | 2.3 GHz | 2.3 GHz |

**Table 1.** Comparison of cloud vendors

## 3. APACHE ZEPPELIN

Apache Zeppelin is Apache project under open-source license Apache 2.0. It aims to provide a web interface to analyze and format large volumes of data processed via spark in a visual and interactive way. It is a notebook style interpreter that enables collaborative analysis sessions sharing between users. Zeppelin is independent of the execution framework itself. Current version run on top of Apache Spark but it has pluggable interpreter APIs to support other data processing systems. More execution frameworks of type SQL-like backends such as Hive, Tajo, MRQL can also be added.

### 3.1. Background

Large scale data analysis workflow includes multiple steps like data acquisition, pre-processing, visualization, etc and may include inter-operation of multiple different tools and technologies. With the widespread of the open source general-purpose data processing systems like Spark there is a lack of open source, modern user-friendly tools that combine strengths of interpreted language for data analysis with new in-browser visualization libraries and collaborative capabilities.

Zeppelin initially started as a GUI tool for diverse set of SQL-over-Hadoop systems like Hive, Presto, Shark, etc. It was open source since its inception in Sep 2013. Later, it became clear that there was a need for a greater web-based tool for data scientists to collaborate on data exploration over the large-scale projects, not limited to SQL. So Zeppelin integrated full support of Apache Spark while adding a collaborative environment with the ability to run and share interpreter sessions in-browser.

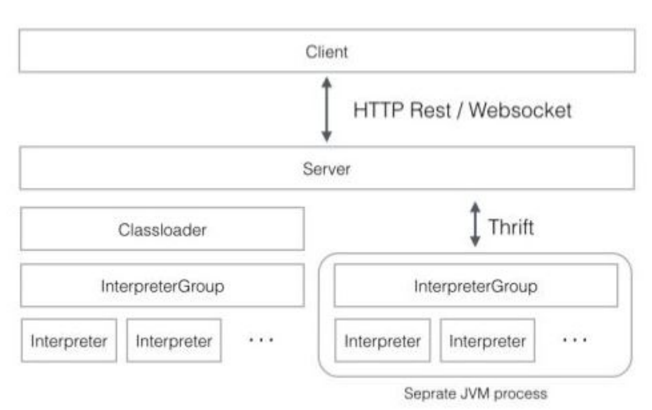


**Fig. 1.** Zeppelin Architecture

### 3.2. Zeppelin Features

Currently, Apache Zeppelin multipurpose notebook supports the following functionalities.

1. Data Ingestion
2. Data Discovery
3. Data Analytics
4. Data Visualization
5. Collaboration

### 3.3. Zeppelin Architecture

#### *3.3.1. Client*

Apache Zeppelin is a client based application. Analytics can be done with latest version of modern browsers. Anyone with details of the host details, port on which zeppelin is listening and access to the zeppelin interpreter can execute or view the notebooks.

#### *3.3.2. Server*

Apache Zeppelin is a web-server based application. Zeppelin listens on a port and application communicates to server through this port. This server-client based architecture facilitates sharing of notebooks and collaboration.

#### *3.3.3. Classloader*

Classloader loads the essential classes and configuration for running of Zeppelin. This also loads spark context as base interpreter. This loads additional interpreter and their classes when the new interpreters are configured and saved.

#### *3.3.4. Multiple Language Backend*

Apache Zeppelin interpreter concept allows any language/data-processing-backend to be plugged into Zeppelin. Currently Apache Zeppelin supports many interpreters listed below

1. Apache Spark
2. Python
3. JDBC
4. Markdown
5. Shell

Adding a new language backend is simple and shown in the next sections

#### 3.3.5. Apache Zeppelin Interpreter

Apache Zeppelin interpreter is a language backend. For example to use python code in zeppelin, it is needed to have a python interpreter. Every interpreter belongs to an InterpreterGroup. Interpreters in the same InterpreterGroup can reference each other. For example SparkSqlInterpreter can reference SparkInterpreter to get the SparkContext from it while they're in the same group.

InterpreterSetting is configuration of a given InterpreterGroup and a unit of start/stop interpreter. All interpreters in the same InterpreterSetting are launched in a single, separate JVM process. The interpreter communicates with Zeppelin engine via Thrift.

#### 3.3.6. Create your own Interpreter

To create a new interpreter we need extend org.apache.zeppelin.interpreter class and implement some methods. We can also include org.apache.zeppelin:zeppelin-interpreter:[version] artifact in our build system and put the jars under the interpreter directory with a specific directory name. Zeppelin server reads interpreter directories recursively and initializes interpreters including the new interpreter that is recently added.

There are three locations where you can store your interpreter group, name and other information. Zeppelin server tries to find the location below. Next, Zeppelin tries to find interpreter-setting.json in your interpreter jar.

zeppelin_interpreter_dir/your_own_interpreter_dir/ interpreter-settings

## 4. DEPLOYMENT

Zeppelin works with Spark deployed across clusters. To deploy Zeppelin and Spark across clusters, Ansible and cloudmesh client integrated with python CMD is used. Refer our code for implementation. Each component and their brief usage is explained in this section.

### 4.1. Cloudmesh Client

Cloudmesh client is a command line based tool to access and manage multiple cloud environments. Cloudmesh client can also be used to define security group and monitor cloud environments. Cloudmesh client is used in the project to boot, delete and define security group to enable firewall settings.

### 4.2. Ansible

Ansible is an automation tool to automate application deployment, maintenance and configuration management. Ansible is used to deploy jdk, openssh, spark and zeppelin across instances that are boot using cloudmesh client.

Ansible playbook is used to write and execute automated deployment. To deploy zeppelin and spark, playbooks are created with different roles like zeppelin, spark, ssh, jdk, start and stop tasks for each cloud with different variable files. Each variable file have cloud specific environment variables like cloud user, home folder and permissions for directory etc. Along with the variable files and separate role files, an individual playbook that calls start and stop tasks for zeppelin and spark. This is required to launch individual roles like start and stop to be executed through command line.

The playbook developed for deploying spark and zeppelin is configured to install pre-built version of spark and zeppelin instead of building from the code. Ansible downloads the prebuilt version and extract it. Then the extracted version is configured for cluster by setting the IP values of master and slaves of the cluster.

Version of Zeppelin and spark is configured in a variables file to make it easy to customize any version of spark or zeppelin. Ports on which zeppelin and spark listens could be configured in the same along with the locations in which the spark and zeppelin need to be installed.

### 4.3. Security - Cross SSH

In order for spark master and slaves to communicate, zeppelin to communicate with spark master cross SSH need to be enabled between all nodes in the cluster. This is achieved by creating a SSH public and private keys. The private key is encrypted using 'Ansible-valut' and stored in code repository. Then at deployment time same private and public key are distributed across cluster using ansible with decryption.

### 4.4. Putting to gether with CMD

### 4.5. Accessing applications

Python CMD is used to build a command line like interface to put cloudmesh client and ansible together. This interfaces with cloudmesh client to boot cloud instances with required security group and deploy applications using ansible.

Python CMD interface takes number of instances required to boot and launches the number of instances by using cloudmesh client. Once the instances are booted, the details of the instances are stored into an inventory file and config files. Now using the generated inventory and config file ansible playbook is launched. The interface has options to set cloud and user details.

This interface also has capability to deal with local network ip and floating IP based deployment. This enables in-network deployment by using less scarce resources without creating floating IP address. To do this we could set master ip through interface and cloud based spark-zeppelin infrastructure with master-slave using only one floating IP.

The interface also can be used to start and stop zeppelin and/or spark. It calls respective ansible playbooks to execute the task by using the inventory files created earlier.

Zeppelin Notebook is accessible via latest version of browsers like Firefox or Chrome. Zeppelin is configured to listen on port 8080 and Spark UI is available on port 8082 of master instance. By launching the master ip and port 8080, Zeppelin is launched and Spark master instance can be configured in Zeppelin. Now Zeppelin is ready to do visual analytics by taking advantage of Spark parallel computing capability.

Spark applications can also be launched using the command line interface created. This invokes start-all utility of spark to launch master and worker nodes. It is useful in the instances where spark need to run as application instead of using Zeppelin for only analytics.

### 4.6. Boot and Deployment Time

The interface prints time taken to boot the instances and time taken to deploy the application across all the nodes. The time printed are used for benchmarking the deployment. Booting happens in sequence as Chameleon cloud supports sequential booting operations only. Once booting is completed the deployment is done in parallel across different machines in cluster. Refer to the benchmarking section for the time took to deployment time on different clouds.

## 5. DATASET DESCRIPTION

This is real-world dataset[9] collected from a Portuguese marketing campaign related with bank deposit subscription. The business goal is to find a model that can explain success of a contact, i.e. if the client subscribes the deposit. Such model can increase campaign efficiency by identifying the main characteristics that affect success, helping in a better management of the available resources (e.g. human effort, phone calls, time) and selection of a high quality and affordable set of potential buying customers.

The increasingly vast number of marketing campaigns over time has reduced its effect on the general public. Furthermore, economical pressures and competition has led marketing managers to invest on directed campaigns with a strict and rigorous selection of contacts. Such direct campaigns can be enhanced through the use of Business Intelligence (BI) and Data Mining (DM) techniques.

In the benchmarking section we have used three codes to benchmark the Zeppelin software that we have deployed on the Chameleon and Jetstream clouds. All the codes run on the same data set and written in SQL. The code is explained in more detail in the visualization section below

## 6. BENCHMARKING

There are 2 different approaches used in benchmarking which are used for the deployments on clouds where the deployment has been done. They are as follows

1. Deployment Benchmarking
2. Analytical Benchmarking

**Deployment Benchmarking**
This benchmarking deals with the time taken for deploying Apache Zeppelin across machines. Graphs are plotted to visualize the time taken for deployment of Apache Zeppelin with number of machines on x-axis and time taken on the y-axis. The command line script also includes code to record the time taken for the deployment. When the VM's are booted inside the command line wrapper the results also include the amount of time taken to deploy Apache Zeppelin on the virtual machines. The time taken for deploying Apache Zeppelin on different number of machines can be recorded and plotted on a graph to show analyze the increase in amount of time as the number of machines increases. Ideally it is excepted that the graph in the curve flattens out as with increase in the number of machines.

Various factors that influence the deployment benchmarking are as follows.

1. The dependencies that need to be installed on all machines in order to deploy the software.
2. The network traffic can effect the time taken for deployment. For example a bad network might introduce delay in downloading the software on to the machines.
3. The number of machines the software has to be deployed on.

**Analytical Benchmarking**
This benchmarking deals with the time taking for running the analytics on clouds. The same analytics are performed on all clouds on which Apache Zeppelin was deployed and the performance is plotted on graphs

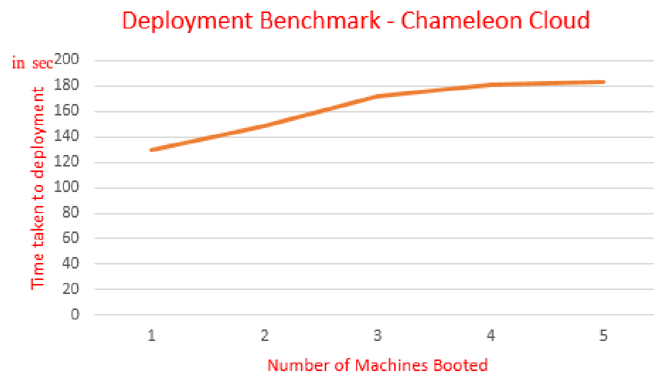


**Fig. 2.** Jetstream Deployment Benchmarking

Various factors that influence the analytical benchmarking are as follows.

1. The size of the data set that the scientist is working on. As the size of the data set it take more time to download the data set and split it across machines.
2. The way the machines are configured. If all the machines lie on the same hardware then the network over head is largely reduced decreasing delays in processing.
3. The complexity of the algorithm. A highly complex algorithm can take longer time time than a simpler algorithm.
4. The size of data set can also effect the running as the algorithm time complexity will increase with the size of the dataset.

Since Cloudmesh client doesn't allow parallel boot of virtual machines the boot time is neglected in the deployment benchmarking

### 6.1. Chameleon Cloud

The Benchmarking for on Chameleon Cloud is done and explained in detail the below 2 sections. The benchmarking is only performed after all the machines are successfully booted and ready for deployment.

#### *6.1.1. Deployment Benchmarking*

Once all the machines are boot the ansible-playbook script is started automatically and the time taken to deploy Apache Zeppelin on the machines is clocked before the start of the deployment and after the end of the deployment. The difference of the end time and start time is the total deployment time. The graph for deployment benchmarking on chameleon cloud explains the various times taken to deploy Apache Zeppelin across machines with changes in the number of machines on Chameleon Cloud.

The time taken for deployment on a single machine is the lowest of all and the time taken for deploying more machines increases with the number of machines. However the graph also starts to flatten out after five machines. Since the deployment is done using ansible playbook the process is parallelized and all the softwares are installed at the same time across all the machines. This process is reflected in the deployment graph shown for chameleon cloud.

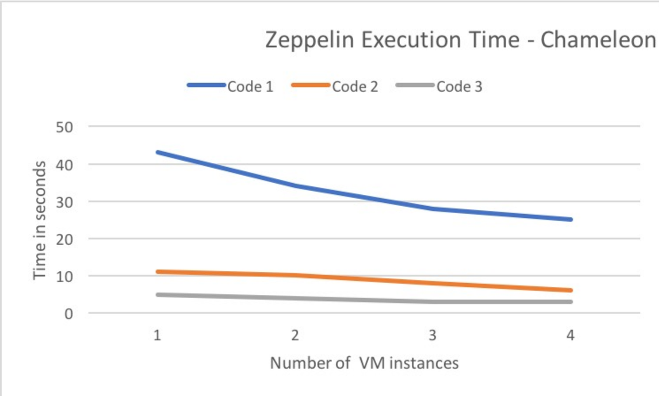


**Fig. 3.** Chameleon Analytics Benchmarking

#### 6.1.2. Analytical Benchmarking

After the deployment of Apache Zeppelin on Chameleon Cloud, the code for the analytics is run on the Apache Zeppelin and the run time is clocked. The run time to process and generate the visualizations is plotted on the y-axis and the number of VMs in the cluster is given on the x-axis. The table below explains this in detail.

**Table 2.** Analytical Benchmarking Chameleon Cloud
Time taken to run codes Vs Machines Count

| VM Count | Code#1 | Code#2 | Code#3 |
|---|---|---|---|
| 1 | 43 | 11 | 5 |
| 2 | 34 | 10 | 4 |
| 3 | 28 | 8 | 3 |
| 4 | 25 | 6 | 3 |

### 6.2. Jetstream Cloud

Similar to Chameleon Cloud, in Jetstream also cloudmesh allows only serial booting of VMs. Hence the boot time of the VMs is ignored in the process of benchmarking the deployments on the Jetstream Cloud.

#### 6.2.1. Deployment Benchmarking

The benchmarking in the Jetstream case is similar to that of the deployment in the Chameleon cloud. The same ansible-playbook script is started automatically and the time taken for deployments are recorded similarly. The below graph explains the amount time taken to deploy Apache Zeppelin on Jetsream cloud when the number of machines are varied.

From the Jetstream deployment benchmarking figure it can be seen that the time taken for deploying zeppelin across virtual machines stops to grow and flattens out as the number of virtual machines start to increase. It can also be noted that there is an increase in the number time taken for deployment the number of virtual machines is less than 4. The primary reason for this initial increase due the additional overhead the master node has to handle for setting up communication with the worker nodes

#### 6.2.2. Analytical Benchmarking

Similar to the analytical benchmarking in the chameleon we also performed the same experiment on Jetstream cloud. The results are presented in the table below.

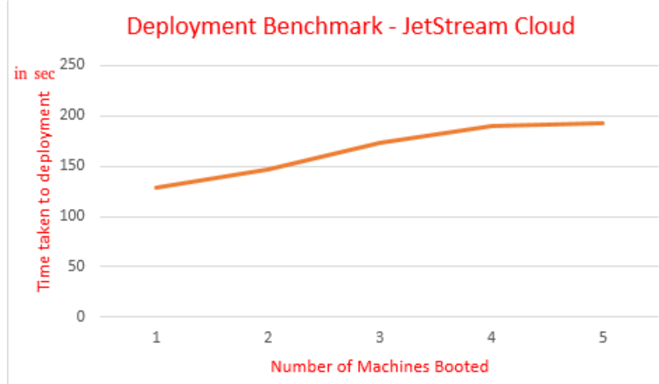


**Fig. 4.** Jetstream Deployment Benchmarking

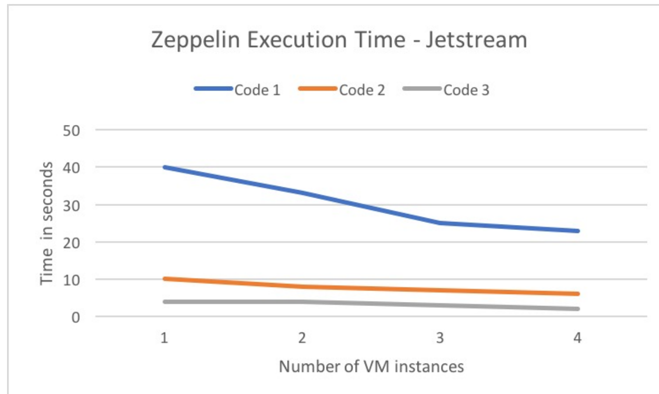


**Fig. 5.** Jetstream Analytics Benchmarking

**Table 3.** Analytical Benchmarking Jetstream Cloud
Time taken to run codes Vs Machines Count

| VM Count | Code#1 | Code#2 | Code#3 |
|---|---|---|---|
| 1 | 40 | 10 | 4 |
| 2 | 33 | 8 | 4 |
| 3 | 25 | 7 | 3 |
| 4 | 23 | 6 | 2 |

Analytics deployment shows a slight decrease in time as number of nodes increased.

### 7. VISUALIZATION WITH ZEPPELIN

All the codes for visualization are written in SQL on Zeppelin. Zeppelin has options to change the type of plots in a click and better present the results. The basic features of zeppelin are presented below through the code examples.

#### 7.0.1. Code 1

This piece of code counts all the people who are below the age of 30, groups them age and then orders the counts by age. The plot below shows this in detail.

```
select age, count(1) value
```

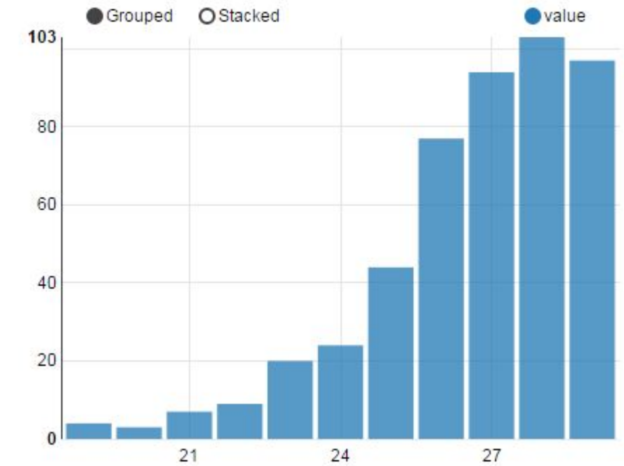


**Fig. 6.** Histogram/ Bar Chart

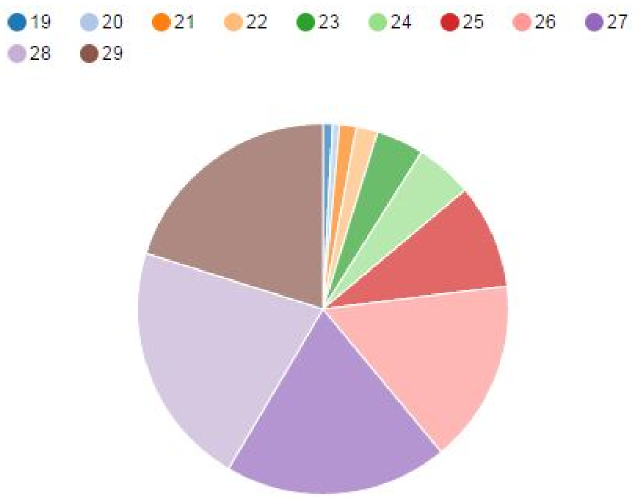


**Fig. 7.** Pie Chart

```
from bank
where age < 30
group by age
order by age
```

A few of the different Types of Visualizations on the same code can be seen the figures below and many others can be explored at on Zeppelin basic tutorials available inbuilt in the Zeppelin notebook. The figures 4, 5 and 6 show how Zeppelin plots Bar Chart, Pie Chart and Line Charts on the Bank data described above.

#### 7.0.2. Code 2

```
select age, count(1) value
from bank
where age < ${maxAge=30}
group by age
order by age
```

In this code above the maxAge parameter acts as an place holder and excepts an user input which is an integer. After the system process the user input then the place holder is replaced

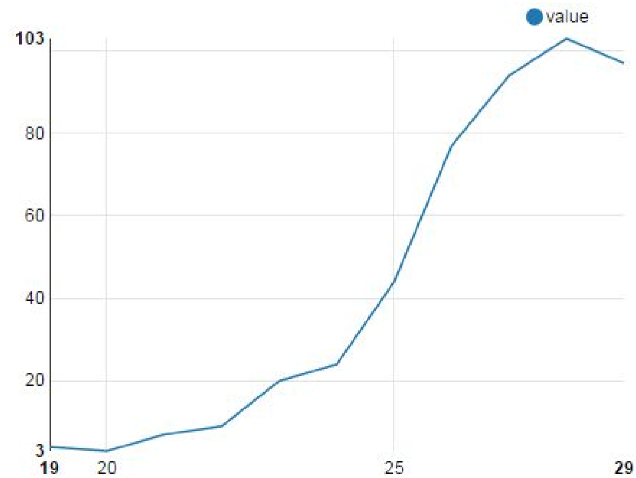


**Fig. 8.** Line Chart

by the input values and Zeppelin executes the code and presents the results.

#### 7.0.3. Code 3

The user input can also be a string and it shown in the code below. Below code takes a string as input and processes the query based on the input received

In the below query the records are picked based on the marital status column, grouped by the age column and then ordered by age to show the count of people on who and their age given their marital status.

```
select age, count(1) value
from bank
where marital="${marital=single,single|divorced|married}"
group by age
order by age
```

## 8. SUPPLEMENTAL MATERIAL

Apache Zeppelin is Quick start tutorials are available on the Apache Zeppelin webpage[10] and can be accessed for free of cost. There are also other Zeppelin works available in the form of notebooks on Zeppelin hub[11].

## 9. CONCLUSION

We are successfully able to deploy Apache Zeppelin across clouds with varying number of machines. The deployment time flattens out after four clusters in both Chameleon and Jetstream clouds. The time taken to run similar zeppelin analytic queries on both clouds are almost similar when the other parameters are fixed.

## 10. EXECUTION PLAN

The following subsections act as a timeline regarding how we broke the project up week-by-week in order to complete the entire project by the desired deadline. This project execution plan is a final draft of the project was implemented during the second half of the semester.

### 10.1. March 6,2017 - March 12,201

This week we discussed about the planned how to implement the project in and came up with approximate deadlines for tasks. We have also revisted the tutorials on the class webpage and referred to official documentation of Apache Zeppelin and came up with a workflow for implementing this project.

### 10.2. March 13,2017 - March 18,201

This week we have installed Cloudmesh on our local machines, completed the tutorials on Cloudmesh present on the class website. We have also accessed on chameleon cloud accounts to boot Vitrual Machines on cloud and logged in successfully into the Virtual Machines.

We have discussed about building a command shell through which we can deploy the clusters with less effort. Hence we looked completed the tutorials on CMD and CMD5 available on the class website. This tutorials have helped us in coming up with a basic outline of the shell that we should develop in order to meet the requirements for deploying Apache Zeppelin on various clouds. We have made a decision to use CMD module in python for this purpose.

### 10.3. March 19,2017 - March 26,201

During this week we have completed the development of the command shell which can start a given number of virtual machines are return their details like the machine name, floating IPs, Static IPs to a file. Other methods like delete, setCloud, getStaticIps, getFloatingIps are also included in the command shell developed over the week. The description for all methods is documented and can accessed from with the shell.

We have discussed the over the deployment of Apache Zeppelin and came up with the dependencies that need to installed on the machines before zeppelin in deployed on to them. We have revisted the ansible tutorials on the class website as we will using ansible to deploy Apache Zeppelin on various clouds

### 10.4. March 27,2017 - April 2,201

Developed and tested code to deploy the Apache Zeppelin on the clusters. Upon successful deployment we have opened ports so that Apache Zeppelin can be accessed through web-interfaces.

### 10.5. April 10,2017 - April 16,201

Integrated the deployment code into the command shell developed previously and tested the deployment chameleon cloud. We have ran into issues with security and VM accessibility. We have fixed the below issues over the week.

1. Fixed deployment issues that might arise to lack of availability of floating point IPs on the chameleon cloud.

2. Fixed security issues and checked if the notebook is accessible through the external web-browsers.

During the week we have also worked on analytics which can be performed on the Apache Zeppelin that has been previously installed on the cloud from a web-page on in external machine. More details about the analytics are discussed in the analytics section below.

### 10.6. April 17,2017 - April 23,201

Review of deployment and developing the final draft of the report for submission.

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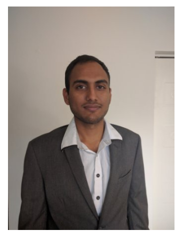

**Veera Marni** received his Bachelors in Technology in Electronics and Communication from SRM University, India and will be receiving his Masters in Data Science from Indiana University in Dec 2017. His research interests are Machine Learning and Big Data. He will be working as Data Scientist intern at Proteous Digital Health during the summer 2017.

## 11. WORK BREAK DOWN:

**Naveenkumar Ramaraju** is responsible for the following

- Ansible scripts for deployment
- Benchmarking on Jetstream

**Veera Marni** is responsible for the following

- Python wrapper using CMD
- Benchmarking on Chameleon
- Zeppelin notebook

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