CAB432 Cloud Computing
Cloud Project - Twittersphere

Prepared for: Associate Professor Jim Hogan
Prepared by: Nikom Dupuskull n9013482
Thanat Chokwijitkul n9234900

Queensland University of Technology (QUT)
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INTRODUCTION

The name of the application is “Twittersphere”, which refers to the universe of Twitter and its habits. This application is a cloud-based query processor and sentiment analyser based on live tweets. Multiple hashtags (keywords emphasised by users) can be submitted to the application and will become a live filter against the inflow of the Twitter messages, monitored by the Twitter Streaming API, the public stream endpoint which streams the public data flowing through Twitter. Any tweet that passes through the filer will be extracted and analysed, then the result will be displayed on the screen, including the filtered messages.

This application can be used to detect emotions and evaluate opinions in the content that people tweet specified by a collection of hashtags. It can qualitatively investigate public’s thoughts and opinions on a particular subject using quantitative scale. In terms of real usage, streaming inflow Twitter messages filtered by a set of hashtags can be used to get opinions or feedback on a particular topic. For instance, live Twitter streaming at any event is one of the efficient way to collect feedback and questions. By referring back to the collected data and performing sentiment analysis, it can give some useful insides of what should be improved and what are particularly appreciated.

Nevertheless, another crucial aspect of this project is to demonstrate the elastic scalability of the application using the Azure cloud service. Hence, it is necessary that the system must be able to generate sufficient workload in order to meet this requirement. As a result, the main computational demand must be based on the number of concurrent queries (hashtags) being processed across the Twitter feed and sentiment analysis.

The application has been deployed via a Docker container, sitting on top of an Azure Linux VM and can be accessed via twittersphere.cloudapp.net.

USE CASES AND SERVICES

Sentiment analysis

- An event manager wants to know what people think about the concert tonight so he can decide to organise the next concert tour with this band or not.

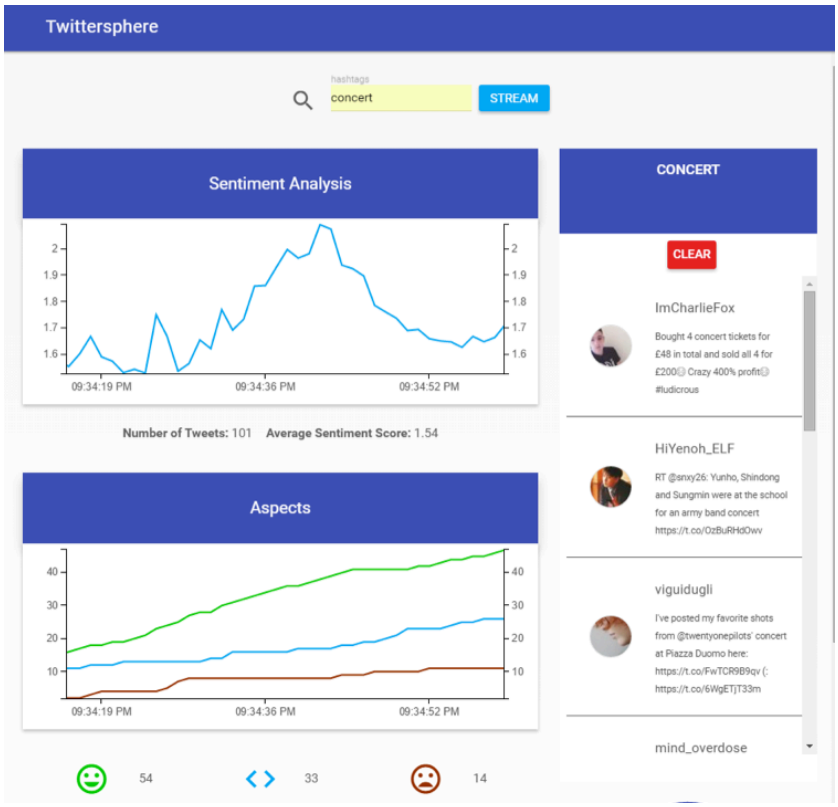

Figure 1: Sentiment analysis

A user can perform a search by inserting keywords in the stream search box. The query will travel from the client side to the server. Then the server makes a query to retrieve the public stream of Tweet data. Each tweet will be analysed by the sentiment module on the server then the results will be displayed on the client side as the Sentiment Analysis Chart and Aspects Chart.

Data record

- A Supervisor from the customer interaction centre wants to know what customers think about their products and also wants to contact the customer in person to increase customer satisfaction and build up a relationship.

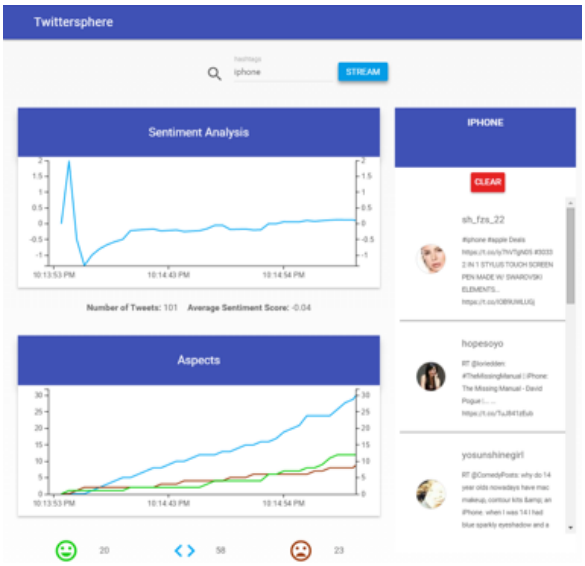

Figure 2: Data record

This case is similar to the previous example. Once the server receives the steam of tweet data, the socket is triggered and creates a data object for each tweet containing username, profile image, content and sentimental score. The data will be stored in JSON format on the server and also displayed on the client side as the tweed feed.

Web performance monitoring

- A web administrator would like to monitor the workload on the system without logging on to the cloud service provider.

Figure 3: Web performance monitoring

In this case, once the application starts, the system will display real-time CPU usage using the OS module, a built-in module providing basic operating system related utilities.

TECHNICAL DESCRIPTION

APPLICATION ARCHITECTURE

This section delineates the architecture of the application, technologies used in both client and server sides, along with how the application has been developed.

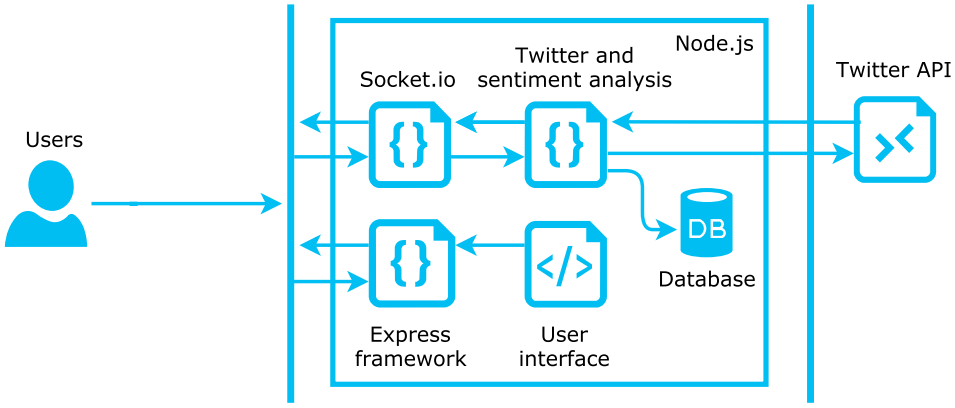

Figure 4: The application architecture diagram

The above diagram illustrates the architecture of the application. When a connection is established, the application will start listening for a specified query event on the socket. When a collection of hashtags is submitted, the application will create a new stream instance using a Twitter client and start listening for events on the stream. Each tweet that passes through the filter will trigger the socket to emit a new data object containing an incoming tweet to the client. At the same time, the client will be listening for the tweet event and update the user interface.

In addition to streaming and emitting tweets to the client, each tweet will also be analysed by the Sentiment module and stored in the local database. At this stage, each message should be successfully classified whether it is positive, neutral or negative by the sentiment score. The system also calculates the mean value of the overall sentiment scores and store the result in another database. The sentiment analysis result then will be emitted to the client and visualised using Epoch, a data visualisation library, to create a real-time graph and display it on the user interface.

Server-side Architecture

Node.js and the Express framework are the main technologies used to build the web server. The major advantage of using Node.js as a server-side language is that it allows developers to create JavaScript isomorphic applications, which are applications that run JavaScript in both client and server sides (Node.js, 2015). However, Node.js alone still lacks of adequate capability to create fully-functional web applications. This is where the Express framework becomes a crucial part in the development process. It is a backend web application development framework written in JavaScript, which contains the common functionalities for single-page, multi-page, hybrid mobile and web applications, and also can be utilised to build application programming interfaces (APIs) or Node.js modules (Wodehouse, 2015).

The following list is the essential modules used in the development process of the application.

Express

Express is the most essential module when developing web application with Node.js. As mentioned before, even though Node.js is a powerful server-side scripting language which contains some basic HTTP functions, whereas those functions cannot efficiently be used build a fully-functional web application. This Sinatra inspired web development framework becomes an effective tool to provides a robust set of features for web applications without obscuring Node features (Express, 2015).

Socket.IO

Socket.IO is an event-driven JavaScript library for real-time applications. It enables bi-directional communication between client and server. it contains two parts, including the server library that can be utilised using Node.js and the client library that runs on a browser (Socket.IO, 2015). In this application, Socket.IO acts as an event-based communication channel between server and client for sending and receiving data in real time.

Twit

Twit is an asynchronous Twitter client library which supports both the REST and Streaming APIs (Tezel, 2015). However, the application only uses the Streaming API due to some limitations of the REST API.

Sentiment

Sentiment uses the AFINN-111 word list as a classifier to perform sentiment analysis (Sliwinski, 2014). However, the module can be trained by overriding the existing words and values or adding a collection of new words. Therefore, the AFINN-165 word list and AFINN-emoticon-8 also have been used in this application to train its classifier to enhance its functionality. The following table is a set of sample results when using the Sentiment library for sentiment analysis.

Sentence	Score	Interpreter
I love Twitter.	3	Positive sentiment (love: 3)
I hate Twitter.	-3	Negative sentiment (hate: -3)
Twitter is very cool, I love it.	4	Positive sentiment (cool: 1, love: 3)
Twitter is irritating, I dislike it.	-5	Negative sentiment (irritating: -3, dislike: -2)
Twitter is an online microblogging service.	0	Neutral sentiment

Table 1: Sentiment analysis results

DiskDB

DiskDB is a lightweight disk based JSON database. Data is stored in a JSON format and can be interacted with a MongoDB-like API (Ravulavaru, 2014). According to the specification, it is not necessary to store the entire search history in a database, whereas persistent is one of the required aspects. As a result, this lightweight database has been utilised to store the data, including tweets and sentiment results, only when the

application remains active. DiskDB identifies different sessions using socket IDs. Event though DiskDB is persistent, but if a particular session is revoked by its end user, all data in that session will be deleted.

Morgan

Morgan is very useful in development since it logs all the request details (GET, POST, PUT and DELETE) onto the terminal console (Express, 2015).

Embedded JavaScript Template (EJS)

EJS has been used to render the main page instead of using the “sendFile” function, which needs the system to identify the root and current directory. However, the “sendFile” function is still used to handle any invalid route, by redirecting users back to the main page.

Mocha

Mocha is a simple, extensible and fast JavaScript test framework running on both server and client. It can be used for unit and integration testing (Mocha, 2015).

SuperTest

SuperTest is a uni test suite developed using SuperAgent, a small progressive client-side library. It provides services for testing HTTP requests (Vision Media, 2015).

Should

Should is very expressive framework-agnostic unit testing module. It keeps all the tests organised and makes error messages more readable and helpful for developers (ShouldJS, 2015).

Client-side Architecture

The application is a single-page web application. HTML and CSS are the default markup and stylesheet languages in developing the user interface, and JavaScript is the main scripting language used on the client side. The design layout of the application is based on the Material Design standard web page layout.

The front-end of this application uses Bower as a package manager, which depends on the Node package manager (npm). The following list is the essential Bower components used in the development process of the application.

AngularJS

AngularJS is a JavaScript framework for single-page applications. One of the benefits of using AngularJS is that it can automatically synchronise data from the user interface with JavaScript objects through 2-way data binding (AngularJS, 2015). It has been heavily used for server-side communication in this application. By using AngularJS with Socket.IO, it becomes a combination that makes real-time communication between client and server plausible.

Epoch

Epoch is a general purpose real-time data visualisation library based on Data-Driven Documents (D3) (Fastly, 2015). Generally, Epoch by itself can be utilised without AngularJS. Therefore, in order to use Epoch with AngularJS, a custom directive is required. This application uses an AngularJS directive wrapper for Epoch called “ng-epoch” for real-time data visualisation.

DEPLOYMENT ARCHITECTURE

The application has been implemented on top of the Microsoft Azure Virtual Machine (IaaS Cloud). In case of deployment, it has been deployed via a Docker container on top on Ubuntu Server VM on Azure.

Microsoft Azure

The application has been implemented on top of the Azure Linux Virtual Machine (Ubuntu Server 15.04), a scalable compute infrastructure in the cloud. The following diagram demonstrates a simple architecture when deploying an application via the Azure Linux VM.

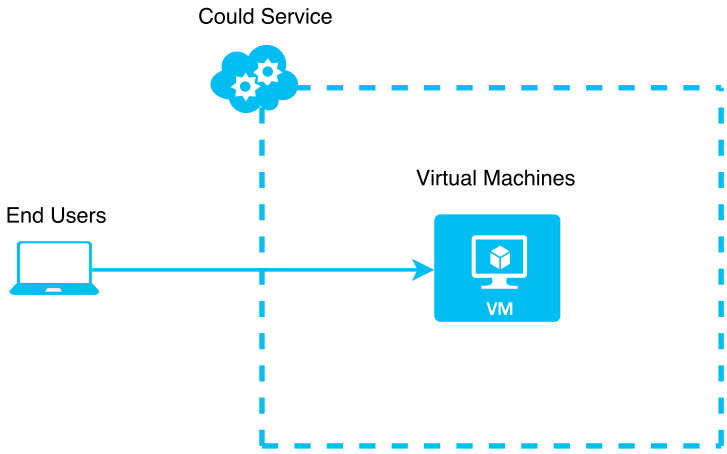

Figure 5: The deployment architecture diagram

At this stage, the application is running inside the Docker container on top of the Azure Ubuntu Server VM. Users can access the web application by using the cloud service’s DNS name. As illustrated in the diagram, a load balancer is not required in this case and scaling is also not possible since there is only one VM running in the cloud service.

If an application is running instances of Web Roles or Worker Roles, it would be much less time consuming to accommodate more workload by adding or removing instances. In case of Virtual Machines, however, the methodology must be different due to its infrastructure. When scaling an an application running Virtual Machines, the provisioned machines in the availability set will be turned on or turned off instead of creating a new machine. The following diagram demonstrates how the application running Virtual Machine can be scaled in the IaaS Cloud.

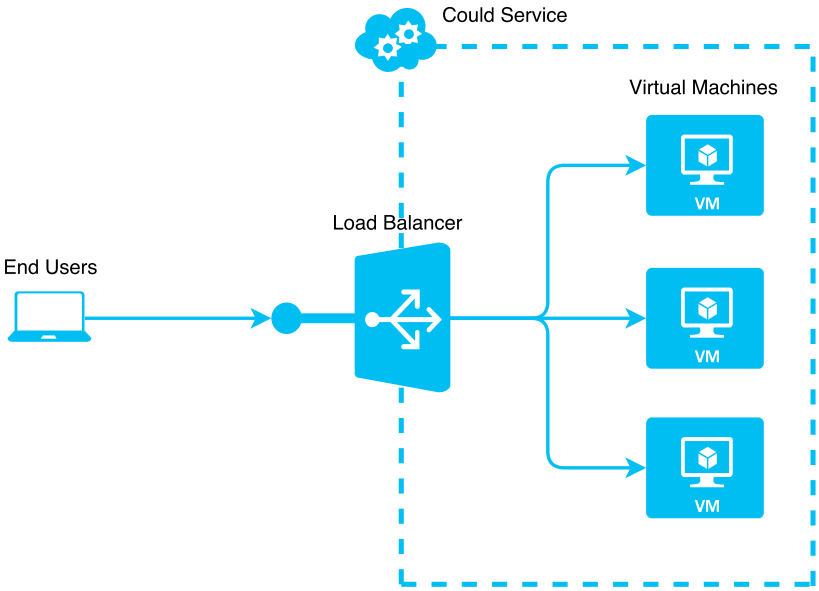

Figure 6: The deployment architecture diagram (autoscaling)

The diagram represents a load-balanced endpoint that is shared among three machines which are in a load-balanced set. A load balancer is required in this case in order to evenly distributed incoming traffic across multiple machines when the scale-up action occurs.

As illustrated in the diagram, three Virtual Machines that serve the same purpose have been added to the availability set. These machines will be turned on in the scale-up action and turned off in the scale-down action, but one of the machines should be initially turned on, others can be initially turned on or turned off. The scaling protocol can be specified based on the average CPU usage or the number of messages in queue. For this application, the scaling protocol is specified based on the average CPU usage. For instance, if the average CPU usage is greater than 70%, another machine in the same availability set will be automatically turned on, and when the percentage is below 50%, one of the machine will be turned off.

Autoscaling Configuration

The average percentage CPU usage is the main parameter used to configure autoscaling for this application. If it increases above or below a specified thresholds, Virtual Machines will be turned on or turned off from the availability set.

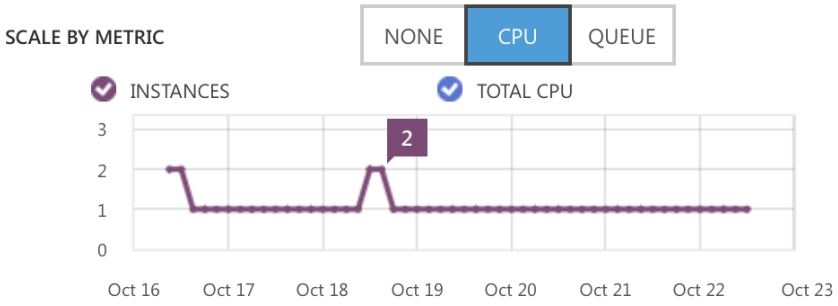

Figure 7: Scale by metric (average CPU usage)

Autoscaling can be configured within the Scale section in a cloud service using the Azure Management Portal. By setting the metric to CPU, the application will be automatically scaled based on the average percentage of the CPU resources that have been used.

Figure 8: Target CPU usage

This slide bar can be used to specified the number of VMs that can be used. The bar on the left specifies the minimum number of VMs and the bar of the right specifies the maximum number of VMs that can be used in the scale-up action.

Figure 9: Target CPU usage

This figure specifies the range of average percentage of CPU usage. if the average CPU usage is higher than the maximum rate, another machine in the same availability set will be automatically turned on. On the other hand, if the percentage is lower than the minimum rate, one of the machines will be turned off.

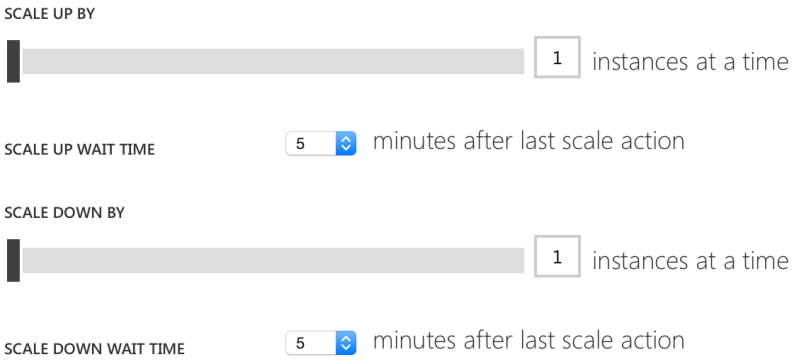

Figure 10: Number of instances to be turned on or off when scaling

These slide bars are used to specify the number of VMs to be turned on each time the application is scaled up and also the number of VMs to be turned off when the application is scaled down. The scale up and scale down wait time can also be configured with the dropdown list below the sliders.

After completing the configuration process, the application should be automatically scaled up or scaled down according to the parameters that have been set in the cloud service.

Docker

Docker has been utilised for the deployment of this project. In order to deploy the application to the IaaS Cloud, a Docker image needs to be built using a Dockerfile, a simple text file containing a sequence of commands to assemble an image. The Dockerfile used in building a software image for this application consists of the following commands:

The latest version of Ubuntu Server on Azure is 15.04. Therefore, the command below tells Docker which operating system will be used to build an image.

```
FROM ubuntu:15.04
```

Identifying the author of Dockerfile.

```
MAINTAINER Thanat Chokwijitkul & Nikom Dupuskull
```

Updating all the packages in the base operating system and install some of the basic applications, including Node.js and Node Package Manager (npm).

```
RUN apt-get update
RUN apt-get install -y nodejs npm
```

Managing an internal path by making a symbolic link between files.

```
RUN ln -s /usr/bin/nodejs /usr/bin/node
```

In addition to npm, this application also needs the Grunt Command Line Interpreter (Grunt CLI) and the Bower package manager for all the client-side components.

```
RUN npm install -g grunt-cli bower
```

Copying the folder containing the source files into the local image.

```
COPY ./Twittersphere /src
```

Installing all the dependencies, including Node modules and Bower components.

```
RUN cd /src; npm install
RUN cd /src/public/libs; bower install --allow-root
```

Telling the Docker container to listen to a specified port (8080) during run time.

```
EXPOSE 8080
```

Setting the default command to execute when creating a new Docker container.

```
CMD ["nodejs", "/src/server.js"]
```

The Dockerfile needs to be located in the root directory on top of the folder containing all the source files. In order to build a software image from the Dockerfile, the following command must be executed:

```
$ sudo docker build -t alexenriquent/twittersphere .
```

Where `alexenriquent` is the DockerHub username and `twittersphere` is the application name. After building the image, the application can be run using the following command:

```
$ sudo docker run --restart=always -p 80:8080 -d alexenriquent/twittersphere
```

As mentioned before, `alexenriquent` is the DockerHub username and `twittersphere` is the application name. The `-p` option will map the external port to the internal port and the `-d` option will deamonise the application and make the container run in the background. Another additional command is the `--restart=always` command, which will automatically restart the container after restarting the VM.

SCALING AND PERFORMANCE

As the amount of workload increases, an application may require additional resources to enable it to perform its operation or handle more traffic. Autoscaling becomes a crucial part in dynamically allocating resources required by the application to deal with the increasing workload along with minimising run time costs. For this application, the autoscaling policies have been configured using the Azure Management Portal. Due to the fact that the application is implemented on top of the Azure Linux VM, it is not possible to create new instances or delete existing instances like Web Roles or Worker Roles. Instead, autoscale will turn on or turn off VMs in the availability set either due to the scale-up or scale-down action.

The scaling strategy used for this application is metrics-based autoscaling, which reacts to the average percentage of CPU utilisation over the past hour. For instance, if the average CPU usage is higher than the maximum CPU rate, one or more VMs will be automatically turned on. On the other hand, if the average CPU usage is lower than the minimum CPU rate, one or more VMs will be automatically turned off.

However, because the metric used in the autoscaling service is average CPU utilisation across all of the VMs over the last hour, if the amount of workload suddenly grows over the maximum rate in a short period of time, autoscale will not be triggered. The system will take approximately 60-minute running average to scale (Microsoft, 2015). Even the scale up and scale down wait time can be configured to 5 minutes, but that cannot confirm that a scale action will be triggered immediately after 5 minutes waiting time.

The following section is an example of how the application can be autoscaled on Microsoft Azure (with 2 VMs).

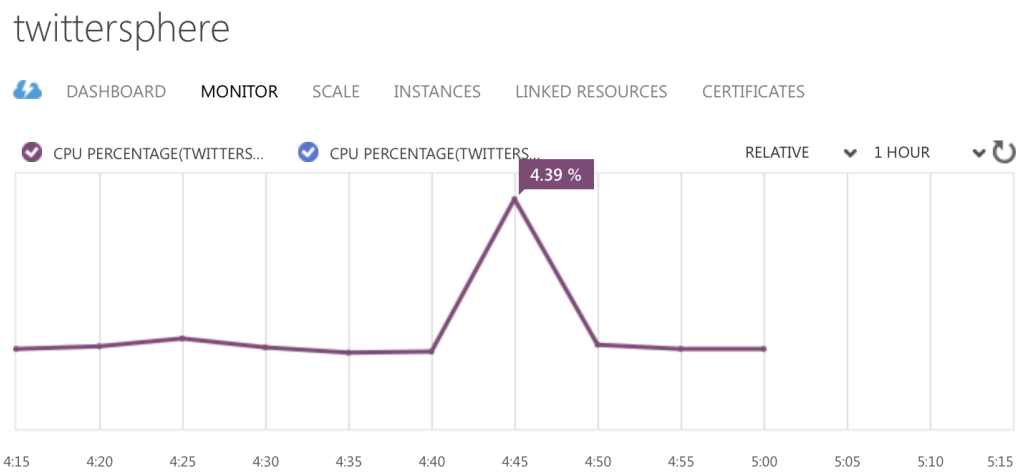

Figure 11: Real-time CPU usage

The above figure shows the real-time CPU usage of two VMs, named “Twittersphere01” and “Twittersphere02”. The purple line and blue line represent the CPU usage of Twittersphere01 and Twittersphere02 respectively. However, only the CPU usage of Twittersphere01 was displayed since Twittersphere02 had been initially turned off.

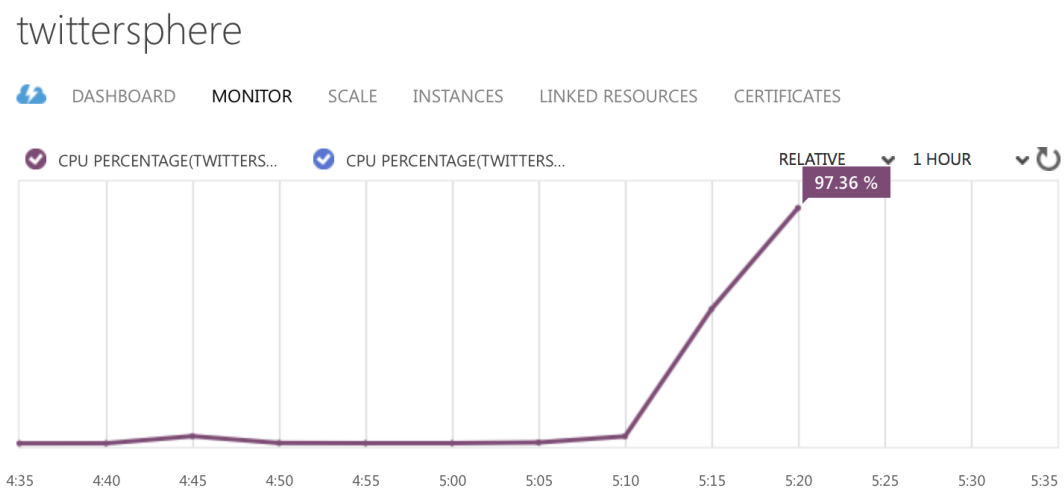

Figure 12: Real-time CPU usage

The CPU usage of Twittersphere01 kept increasing and eventually went higher than the maximum CPU rate, which was 70% at that time. At this stage, the autoscale status of the Twittersphere cloud service was “Autoscale reduced your costs by up to 50%”, which indicates that Twittersphere02 still remained deallocated.

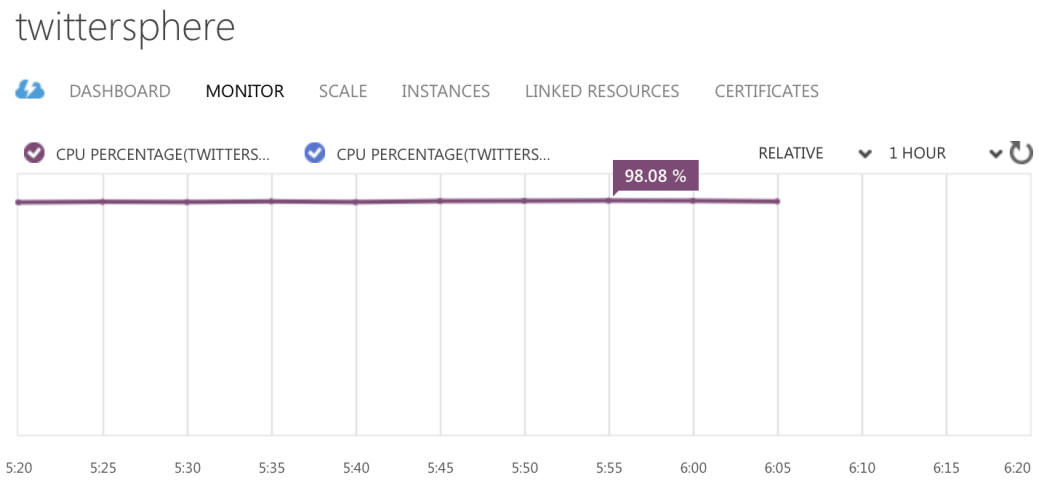

Figure 13: Real-time CPU usage

The CPU usage of Twittersphere01 remained almost stable over the time period. The average CPU usage kept increasing from 74.88% to 93.57%. The autoscale status remained the unchanged.

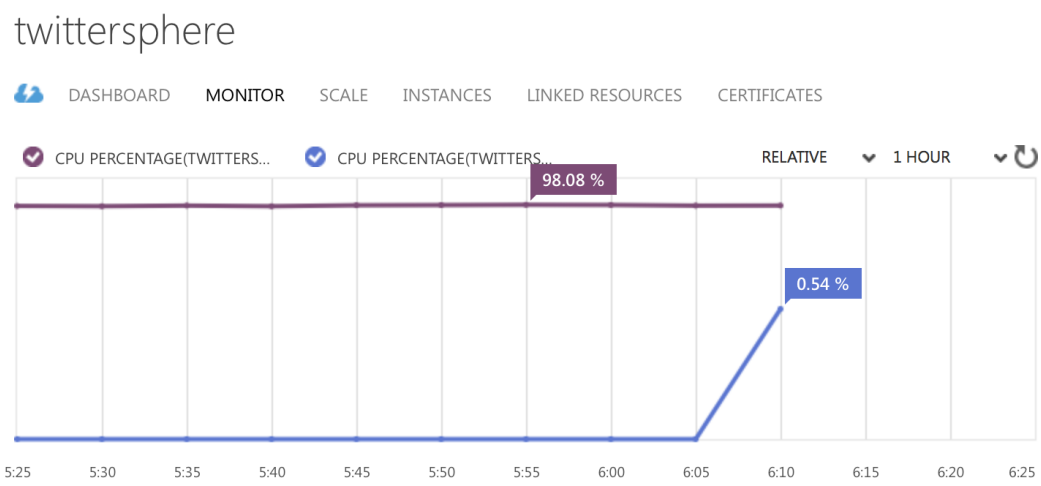

Figure 14: Real-time CPU usage

At the percentage of average CPU usage of 97.73%, Twittersphere02 was automatically turned on, which means the application was successfully scaled up. The total time taken before scaling up was approximately 45 minutes. The autoscale status became “Autoscale is configured and running”.

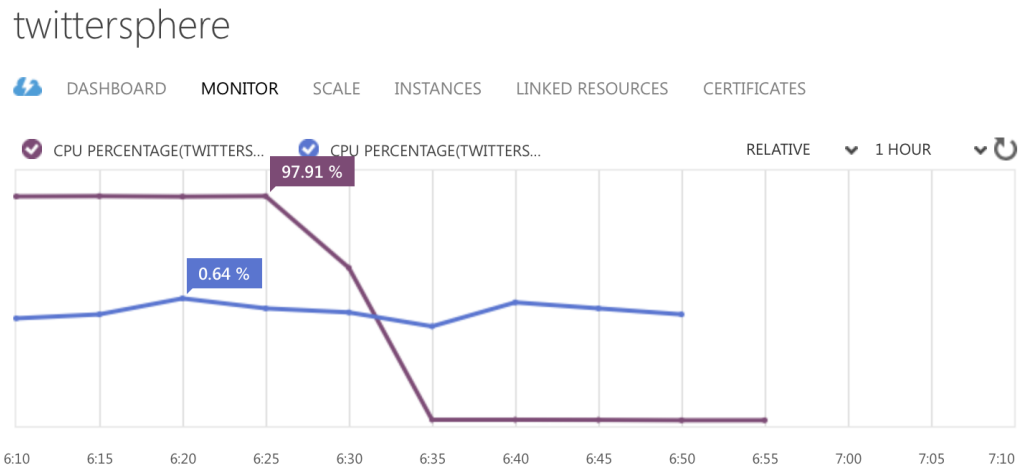

Figure 15: Real-time CPU usage

The application continued running for another 10 minutes before being terminated (removing the search including its history and statistics). According to the graph, the CPU usage of Twittersphere01 rapidly decreased from 97.91% to 2.76% in 10 minutes, then remained stable for another 25 minutes until the average CPU usage became 37.69%, which was lower than the minimum CPU rate (50%). At this stage, Twittersphere02 was automatically turned off and the autoscale status became “Autoscale reduced your costs by up to 50%” again. This means the application was successfully scaled down and also concludes that autoscaling for an application running Virtual Machines functions correctly based on the average percentage of CPU utilisation over the last hour.

TESTING AND LIMITATIONS

This section delineates the testing framework used in the application and limitations of the development process and functionality.

Web Application Testing

Web application testing is a quality assurance process to ensure that the application functions as expected based on its functionalities and use cases.

General Functionalities

ID	Purpose	Expected/Actual	Pass
1	Ensure that the search functionality works correctly when input a single hashtag.	E: The hashtag should become a filter for incoming tweets and the sentiment analysis results should display on the screen. A: The hashtag becomes a live filter for incoming tweets and the sentiment analysis results display on the screen. However, the number of tweets depends on the popularity of the hashtag.	✓
2	Ensure that the search functionality works correctly when input multiple hashtags separated by commas.	E: The hashtags should become a filter for incoming tweets and the sentiment analysis results should display on the screen. A: This functions as expected and the number of tweets is higher. However, the sentiment result may vary due to the sentiment score of each keyword.	✓
3	Ensure that the content panel functions as expected.	E: While streaming, the content panel should display incoming tweets and keep shifting old tweets in case that the number of tweets is higher than 10. A: The content panel functions as expected. However, as the number of hashtags increases, updating and shifting are also accelerated.	✓
4	Ensure that the Sentiment Analysis graph functions as expected.	E: While streaming, the number of tweets and the average sentiment score should be continuously updated in real time and the graph should be updated according to the average sentiment score of the set of hashtags. A: The number of tweets and the average sentiment scores are updated in real time and the live line graph is continuously updated in almost real time. This is acceptable due to the animation delay of the Epoch library.	✓

ID	Purpose	Expected/Actual	Pass
5	Ensure that the Aspect Analysis graph functions as expected.	E: While streaming, the number of positive, neutral and negative tweets should be continuously updated in real time and the graph should be updated according to these data. A: The number of positive, neutral and negative tweets are continuously updated in real time. Addition of these three number will result in the total number of filtered tweets in real time. The live line graph is continuously updated in almost real time. This is acceptable due to the animation delay of the Epoch library.	✓
6	Ensure that the CPU usage gauge functions as expected.	E: Before streaming, the initial percentage CPU usage should be very low. While streaming, it should increases as the number of tweets goes up. A: The gauge is continuously updated according to the real-time percentage of CPU usage. The percentage is very low at first, then increases as as the number of tweets goes up.	✓

Web Test

ID	Test	Check	Notes
1	Links	N/A	No links
2	Forms	✓	Search form is working and displays the results
3	Error messages	N/A	The site provides only search function
4	HTML validation	✓	There are some errors shown caused by using AngularJS which can be ignored.
5	CSS validation	✓	W3C CSS validation service cannot recognize the properties for Epoch graph.
6	Popular browsers	**X**	Chrome, Firefox and Safari working perfectly. IE doesn't show the twitter feed or draw the charts.
7	Web security	✓	Remove all notes & comments (client side)
8	Free of errors	✓	-

Server Side Test

ID	Test	Check	Notes
1	Data test	✓	Able to store twitter feed data
2	HTTP request	✓	Able to make HTTP request

Usability Script Test

ID	Test	Check
1	Check how much CPU usage right now	Success
2	Search for #funny then check the average sentiment score and the number of positive tweets	Success
3	Search for “funny” and see the difference from searching with a hashtag	Success
4	Search with multiple keywords	It takes more time as user must separate keywords by commas

Accessibility Test

ID	Criteria	Check
1	Provide text alternatives for all non-text content; use “alt” for the IMG tag	N/A
2	Ensure that information and structure can be separated from presentation; the website should be working without CSS and all fields should be labelled	✓
3	Make it easy to distinguish foreground information from its background; the colour contrast must be at least 5:1 with resizable text	✓
4	Make all functionality operable via a keyboard interface; be able to use the keyboard to navigate around the website	✓
5	Provide mechanisms to help users find contents, orient themselves within it, and navigate through it; the navigation & page title are clear and meaningful, and all links are working, have a suitable purpose and are clearly identified.	✓
6	Make text content readable and understandable; correct spelling & gramma, no jargon, and explain the abbreviations	✓
7	Make the placement and functionality of content predictable; giving a warning for any changing formats (pop-up window, form and previous page)	✓

Test Reviews

ID	Area	Security	Compromises
1	IE doesn't show the tweets and charts	Critical	IE doesn't support AngularJS and Epoch. In this circumstance, we cannot fix these problems.

Unit Testing

The application utilises 3 Node modules for unit testing, including Mocha, Should and SuperTest. Even though unit testing is not a huge part of the project, but it is necessary to ensure that all the routes function as expected. Since it is a single-page web application, the main route should direct to the main page, and other invalid route may also redirect to the main page. The unit testing within the application can be run using the "npm test" command, the results should be similar to the following:

```
Main route
    GET /
GET / 200 8.265 ms - 4473
      ✓ should return 200 (43ms)
GET / 200 2.324 ms - 4473
      ✓ should display content as "text/html"
    GET /test
GET /test 200 3.850 ms - 4473
      ✓ should return 200
GET /test 200 1.535 ms - 4473
      ✓ should display content as "text/html"

  4 passing (79ms)
```

Limitations

The application has utilised the Twitter Streaming API to gain access to Twitter's global stream of tweet data. By using the public stream endpoint, the system can retrieve the streams of public data flowing through Twitter filtered by a collection of hashtags. Even though polling and REST API rate limit are not worrisome issues in this case, the Twitter Streaming API still has its own limitations.

This application does not require users to login and use each individual's credential as a token for data streaming. Therefore, using only one set of credentials over and over again can reach the connection rate limit. According to the documentation related to the connecting to a streaming endpoint issue, Twitter will automatically close a streaming connection if a Twitter client establishes too many connections that exceed the streaming rate limit with the same credentials. In this case, the oldest connection connected to the stream endpoint will be terminated (Twitter, 2015). When the client is disconnected, it will attempt to reconnect to the stream endpoint immediately, if the reconnect fails, it will be slowed down. Even though the exact number of connections or attempt to reconnect that causes the rating limiting to occur has never been specified, but it is crucial not to increase the number of connections if a HTTP 420 response is received. This possibly causes the IP address to be blocked for a period of time (Ibid.).

POSSIBLE EXTENSIONS

The Cloud Scaling Project *Twittersphere* illustrates the use of sentiment analysis from twitter feed. There are over 350,000 tweets sent per minute or 500 million tweets per day (Oreskovic, 2015) and 316 million active accounts (Smith, 2015). The application can filter specific tweets then analyse this information and give instant results in a user friendly format while the tweets are recorded on the server.

The application can be used as a social media monitoring tool for business to respond to client feedback and to make predictions for marketing strategy planning. These uses could increase the brand loyalty and improve customer satisfaction. Additionally, the application can capitalise on real time responses to people for example, “the Obama administration used sentiment analysis to gauge public opinion to policy announcements and campaign messages ahead of 2012 presidential election.”(Smith, 2015). The potential for a complaint or negative tweet to be seen by other users may increase exponentially as the average number of followers per twitter user is 208 (Smith, 2015). The ability to identify any potential problem quickly and handle it effectively are obviously very important.

The application can analyse the tweets and categorise them into positive, neutral and negative tweets based on text and emoticon analysis. However, human language is very complex so teaching a machine to understand the human context is key. Understanding the context is likely to allow a more accurate interpretation indicating if the person was being sarcastic, surprised, angry or disappointed (Bannister, 2015). Making sentiment analysis more accurate is not only useful at the present time but may enhance the ability to predict future trends.

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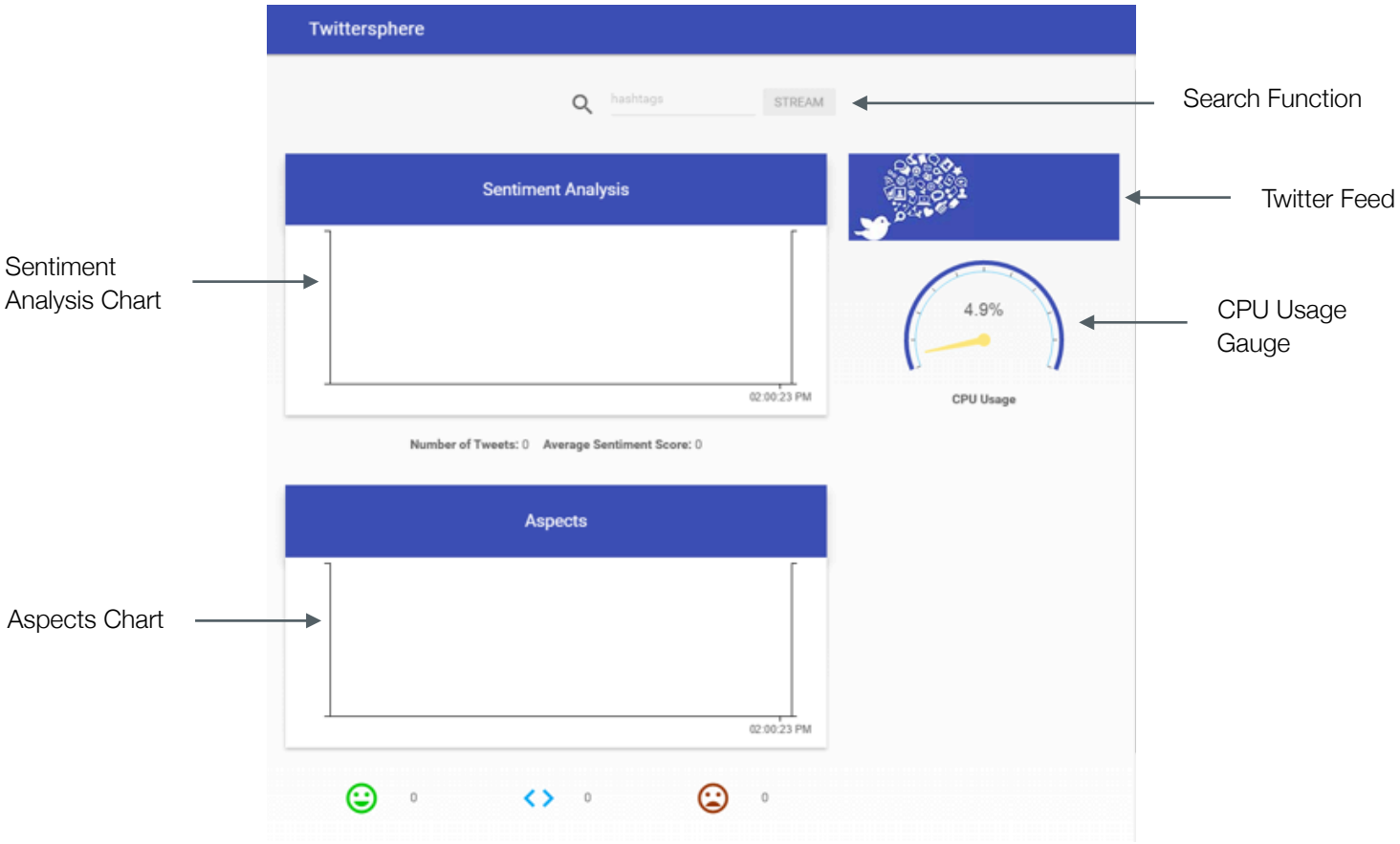
APPENDIX A - USER GUIDE

Twittersphere is a web application that provides you a simple way to perform sentiment analysis from twitter feed. It has the following features:

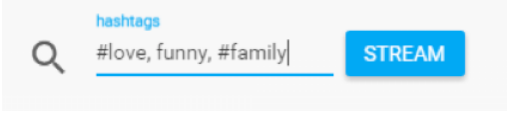
- Search function
- Twitter feed
- Sentiment Analysis Chart
- Aspects Chart
- CPU Usage gauge



Appendix A Figure 1: Features

Search Function

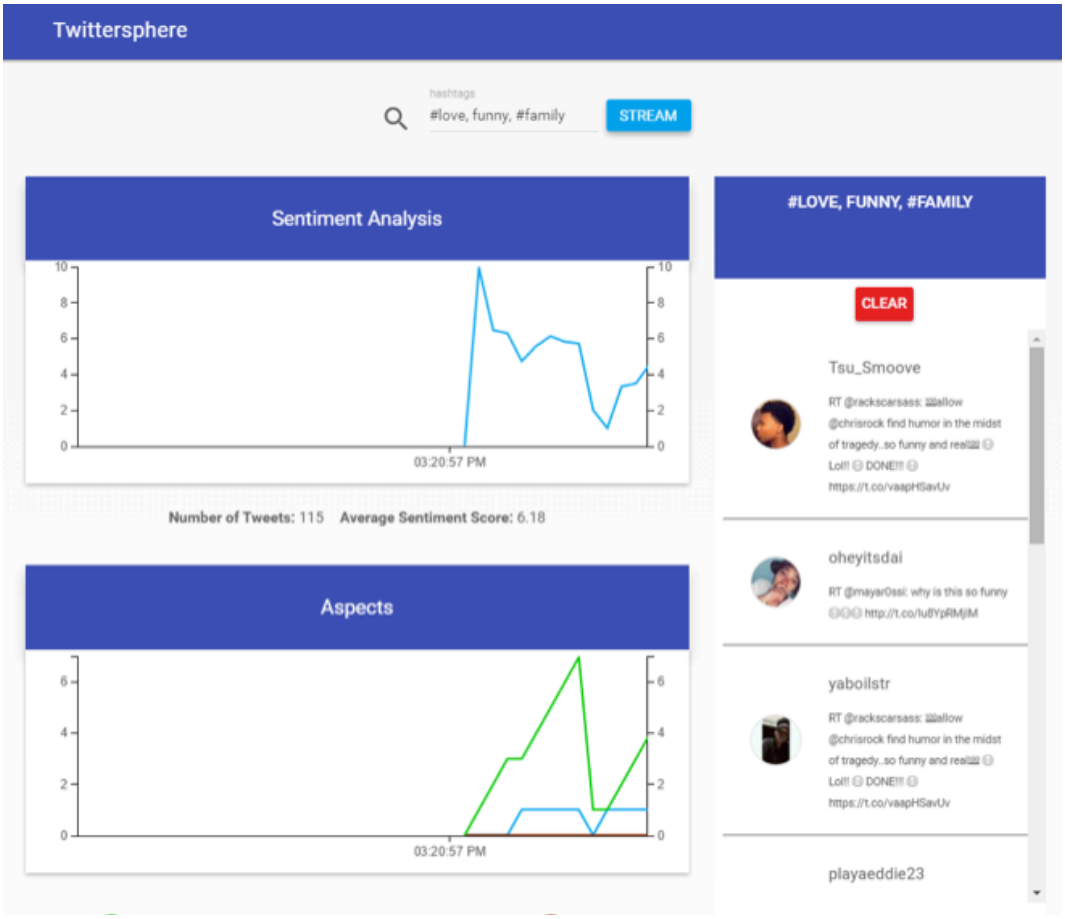
To perform sentiment analysis requires a search term. Users can use a single keyword or multiple keywords separated with a comma. If the keyword contains a hashtag, the twitter feed result will focus on that specific hashtag.



Appendix A Figure 2: Search function

Twitter Feed

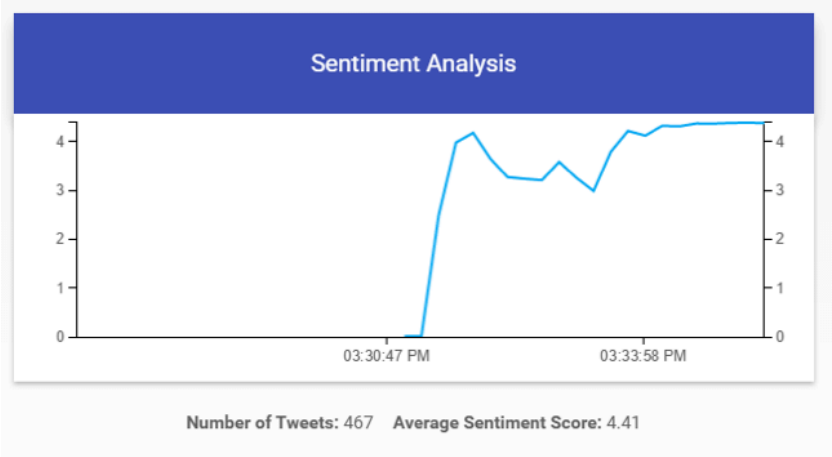
Once the search term has been submitted, the relevant tweets will be display on the right hand side. Each tweet shows the username, profile image and content.



Appendix A Figure 3: Twitter feed

Sentiment Analysis Chart

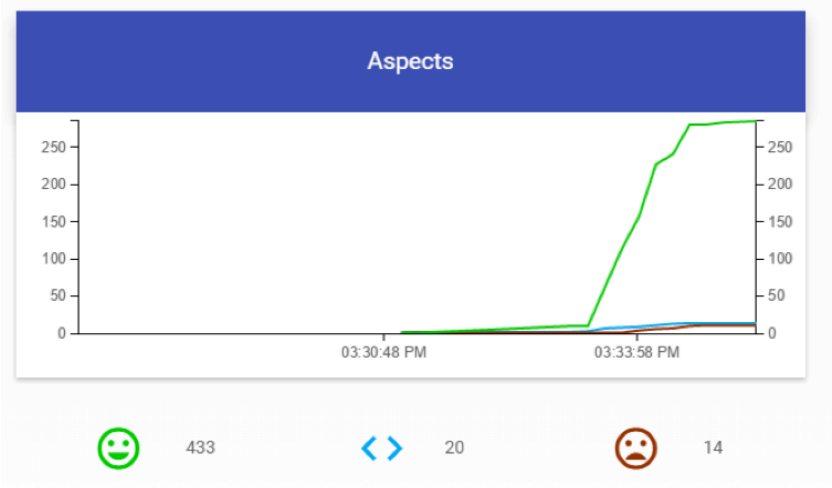
All of the tweets will be analysed using text and emoticon analysis. The average sentiment score will be plotted on the live line chart and displayed with the number of tweets at the bottom of the chart.



Appendix A Figure 4: Sentiment analysis chart

Aspects Chart

Once the tweet has been analysed, it will be categorised into three different groups; positive, neutral and negative tweet.



Appendix A Figure 5: Aspects chart

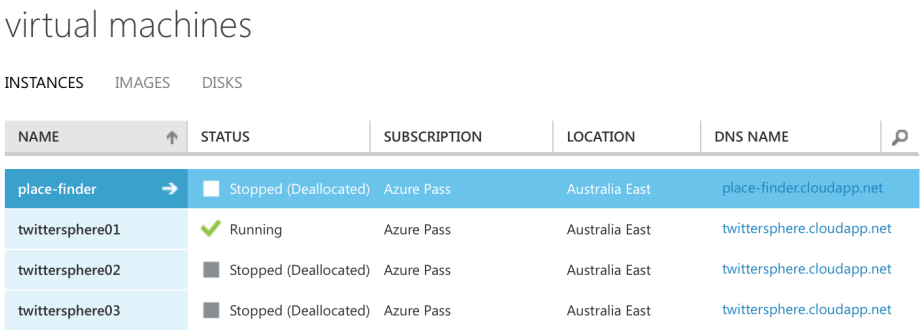
CPU Usage Gauge

The cpu usage gauge represents how much work it is doing or the amount of resources has been used on the server. After it reaches the setting limitation which in this case is 60 percent, the server will be triggered to scale up to reduce the workload or otherwise to scale down.

Appendix A Figure 6: CPU usage gauge

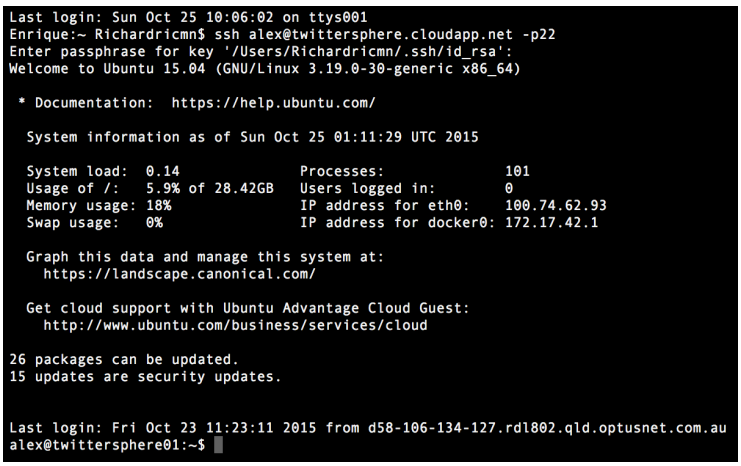
APPENDIX B - DEPLOYMENT INSTRUCTIONS

The application has been implemented on top of the Microsoft Azure Virtual Machine (IaaS Cloud). In case of deployment, it has been deployed via a Docker container on top on Ubuntu Server VM on Azure (Ubuntu Vivid 15.04). The section outlines the instructions on how to deploy the application.



Appendix B Figure 1: Provisioned Virtual Machines

1. This application needs to be deployed to an IaaS Cloud. It is necessary that one or more Virtual Machines need to be created. Additionally, this project also needs demonstrate the elastic scalability of the application using the Azure cloud service. As illustrated in the figure above, three VMs, named Twittersphere01, Twittersphere02 and Twittersphere03, has been provisioned to supply the requirements.



Appendix B Figure 2: Accessing the Twittersphere01 VM

2. VMs can be accessed by using SSH keys with the following commands for Twittersphere01, Twittersphere02 and Twittersphere03 respectively.

```
$ ssh alex@twittersphere.cloudapp.net -p22
$ ssh alex@twittersphere.cloudapp.net -p58044
$ ssh alex@twittersphere.cloudapp.net -p61690
```

```
General form
$ ssh <vm-username>@<cloud-service-DNS-name> -p<ssh-port-number>
```

To explain the above command, “ssh” is the OpenSSH SSH client used to connect to a remote server, following by a username, a cloud service DNS name and an SSH port number which must be distinct for each VM.

3. Set up the environment of each VM, the software needed for this project are Docker and Git.

Docker Installation

To install Docker, the kernel version must be 3.10 at minimum. Starting with adding the new gpg key.

```
$ sudo apt-key adv --keyserver hkp://pgp.mit.edu:80 —recv-keys
58118E89F3A912897C070ADBF76221572C52609D
```

Create a file named `docker.list` in `/etc/apt/sources.list.d/` and put the following link into the file.

```
deb https://apt.dockerproject.org/repo ubuntu-vivid main
```

Then update the system and verify that `apt` pull all the packages from the new repository

```
$ sudo apt-get update
$ sudo apt-get purge lxc-docker*
$ sudo apt-cache policy docker-engine
```

The final step is to install Docker with the following command.

```
$ sudo apt-get install docker-engine
```

Git Installation

To install git, another repository needs to be added to the system.

```
$ sudo add-apt-repository ppa:git-core/ppa
```

Then update all the packages and install Git using `apt`.

```
$ sudo apt-get update
$ sudo apt-get install git
```

4. Clone the repository containing the application from GitHub and build it with a Dockerfile (see Appendix C for Dockerfile).

Clone the project with the git clone command.

```
$ git clone https://github.com/alexenriquent/cloud-project.git
```

```
General form
$ git clone <https-clone-url>
```

Build the application using the Dockerfile.

```
$ sudo docker build -t alexenriquent/twittersphere .
```

```
General form
$ sudo docker built -t <application-name>
```

5. Run the built image with the following command.

```
$ sudo docker run --restart=always -p 80:8080 -d alexenriquent/twittersphere
```

```
General form
$ sudo docker run --restart=always -p <external-port>:<internal-port> -d
<application-name>
```

In the command, `alexenriquent` is the DockerHub username and `twittersphere` is the application name. The `-p` option will map the external port to the internal port and the `-d` option will deamonise the application and make the container run in the background. Another additional command is the `--restart=always` command, which will automatically restart the container after restarting the VM.

APPENDIX C - DOCKERFILE

```
# Dockerfile to build Twittersphere
# Based on Ubuntu

# Set the base image to Ubuntu 15.04
FROM ubuntu:15.04

# File author / maintainer
MAINTAINER Thanat Chokwijitkul & Nikom Dupuskull

# Download and update packages
RUN apt-get update

# Install basic applications
RUN apt-get install -y nodejs npm

# Make a symbolic link between files
RUN ln -s /usr/bin/nodejs /usr/bin/node

# Install Bower and Grunt
RUN npm install -g grunt-cli bower

# Copy the application folder inside the container
COPY ./Twittersphere /src

# Run the command to install node modules
RUN cd /src; npm install

# Run the command to install bower dependencies
RUN cd /src/public/libs; bower install --allow-root

# Expose port
EXPOSE 8080

# Set the default command to execute when creating a new container
CMD ["nodejs", "/src/server.js"]
```

APPENDIX D - MODULE DEPENDENCIES & LIBRARIES

NODE PACKAGE MANAGER (NPM)

Express

```
$ npm install express
```

URL: http://expressjs.com
GitHub: https://github.com/strongloop/express

Socket.IO

```
$ npm install socket.io
```

URL: http://socket.io
GitHub: https://github.com/socketio/socket.io/

Twit

```
$ npm install twit
```

URL: https://www.npmjs.com/package/twit
GitHub: https://github.com/ttezel/twit

Sentiment

```
$ npm install sentiment
```

URL: https://www.npmjs.com/package/sentiment
GitHub: https://github.com/thisandagain/sentiment

DiskDB

```
$ npm install diskdb
```

URL: https://www.npmjs.com/package/diskdb
GitHub: https://github.com/arvindr21/diskdb

Morgan

```
$ npm install morgan
```

URL: https://www.npmjs.com/package/morgan
GitHub: https://github.com/expressjs/morgan

EJS

```
$ npm install ejs
```

URL: http://ejs.co
GitHub: https://github.com/tj/ejs

Mocha

```
$ npm install mocha
```

URL: https://mochajs.org
GitHub: https://github.com/mochajs/mocha

SuperTest

```
$ npm install supertest
```

URL: https://www.npmjs.com/package/supertest
GitHub: https://github.com/visionmedia/supertest

Should

```
$ npm install should
```

URL: https://www.npmjs.com/package/should
GitHub: https://github.com/shouldjs/should.js

BOWER PACKAGE MANAGER

AngularJS

```
$ bower install angular
```

URL: https://angularjs.org
GitHub: https://github.com/angular/angular.js

Angular Material

```
$ bower install angular-material
```

URL: https://material.angularjs.org
GitHub: https://github.com/angular/material

Angular Socket.IO

```
$ bower install angular-socket-io
```

GitHub: https://github.com/btford/angular-socket-io

jQuery

```
$ bower install jquery
```

URL: http://jquery.com

D3

```
$ bower install d3
```

URL: http://d3js.org
GitHub: https://github.com/mbostock/d3

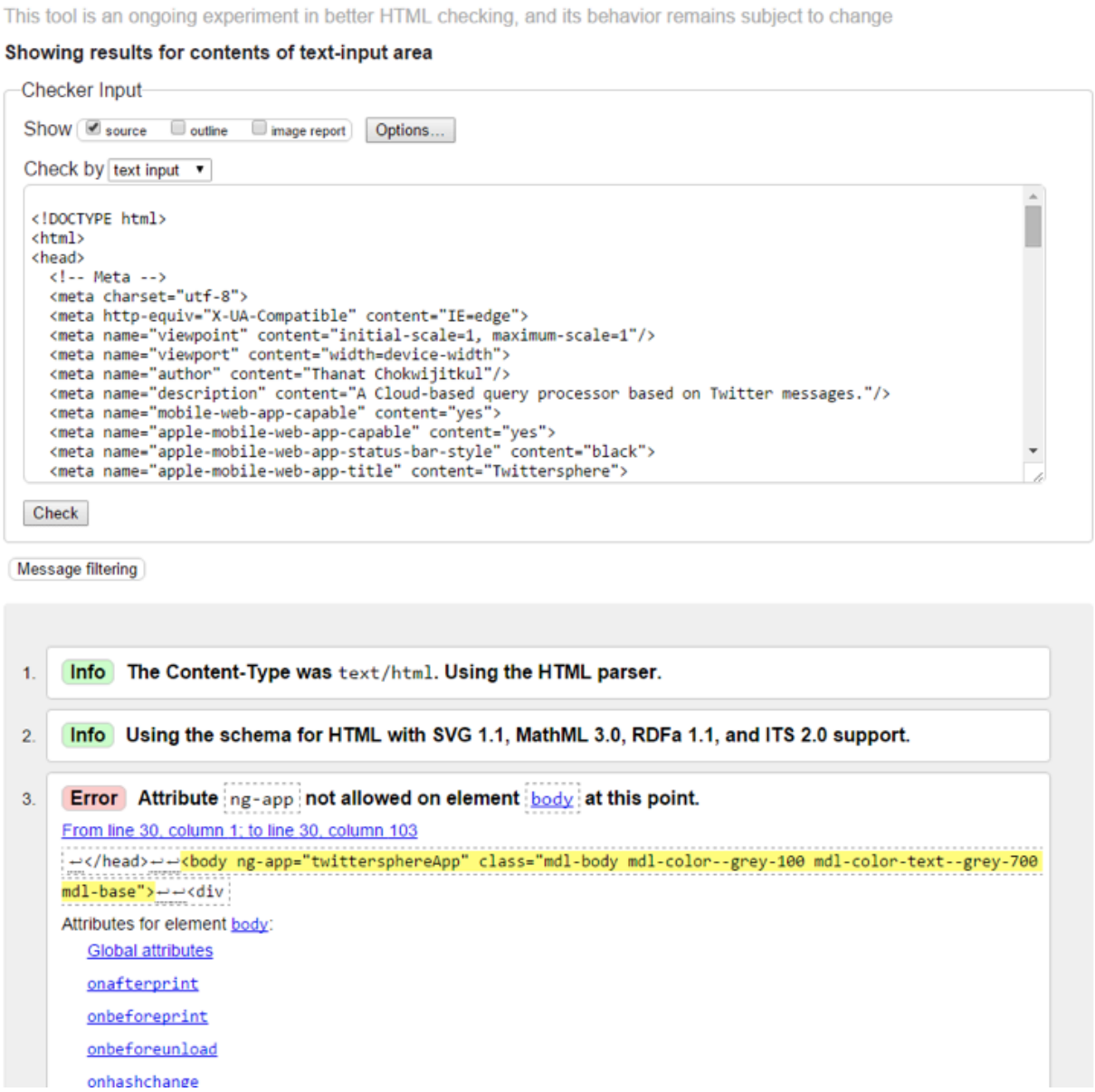
ng-epoch (Angular directive for Epoch)

```
$ bower install ng-epoch
```

URL: https://fastly.github.io/epoch/ (Epoch)
URL: http://dainbrump.github.io/ng-epoch/ (ng-epoch)
GitHub: https://github.com/epochjs/epoch (Epoch)
GitHub: https://github.com/dainbrump/ng-epoch (ng-epoch)

APPENDIX E - TEST RESULTS

HTML Validation

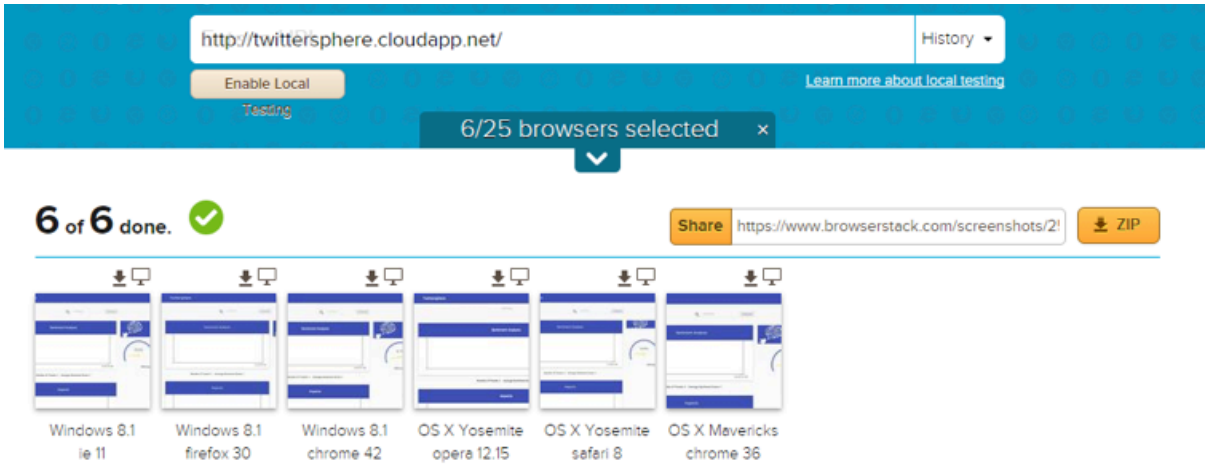


Appendix E Figure 1: HTML validation

CSS Validation

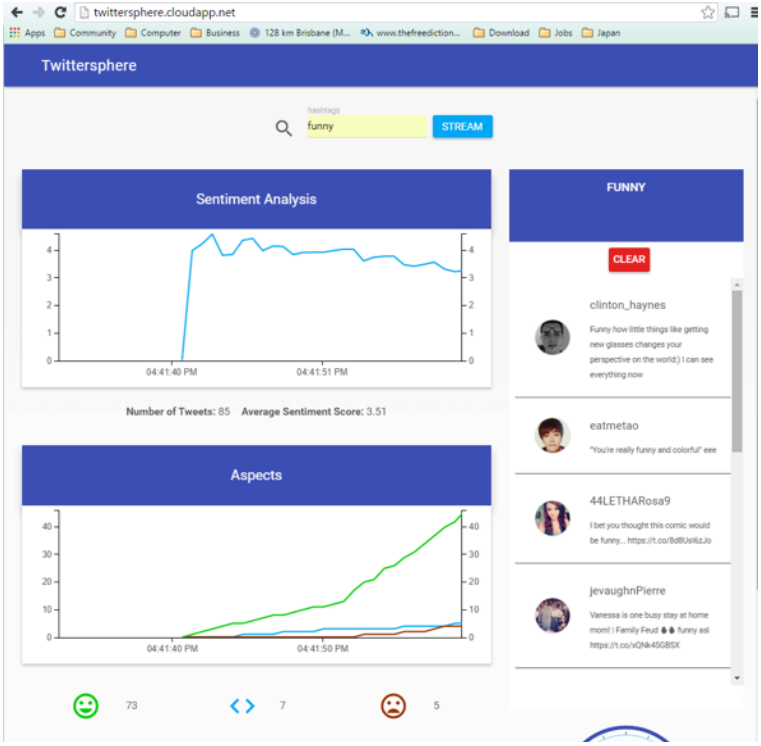
Appendix E Figure 2: CSS validation

Browser Compatibility



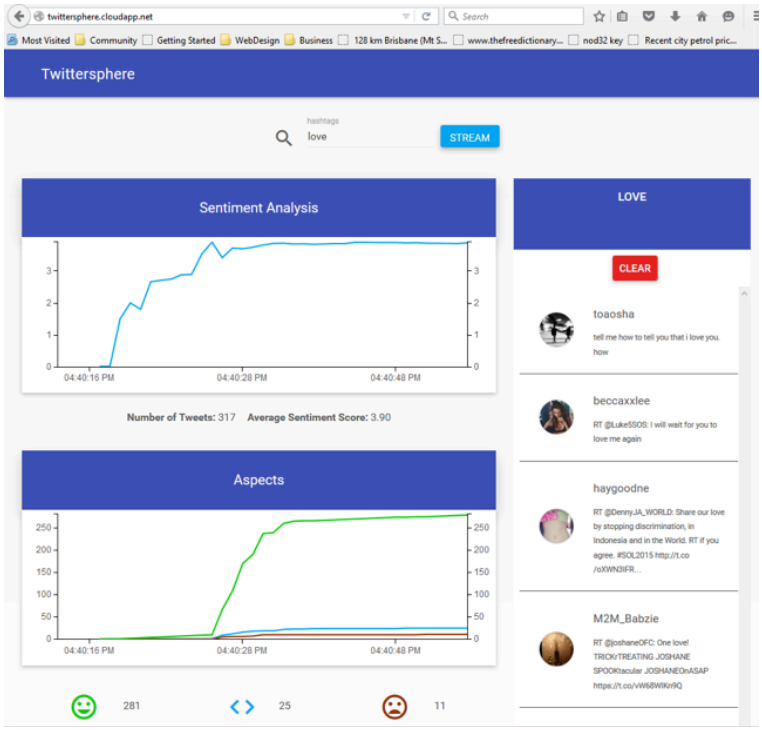
Appendix E Figure 3: Browser compatibility

Browser Compatibility (Google Chrome)



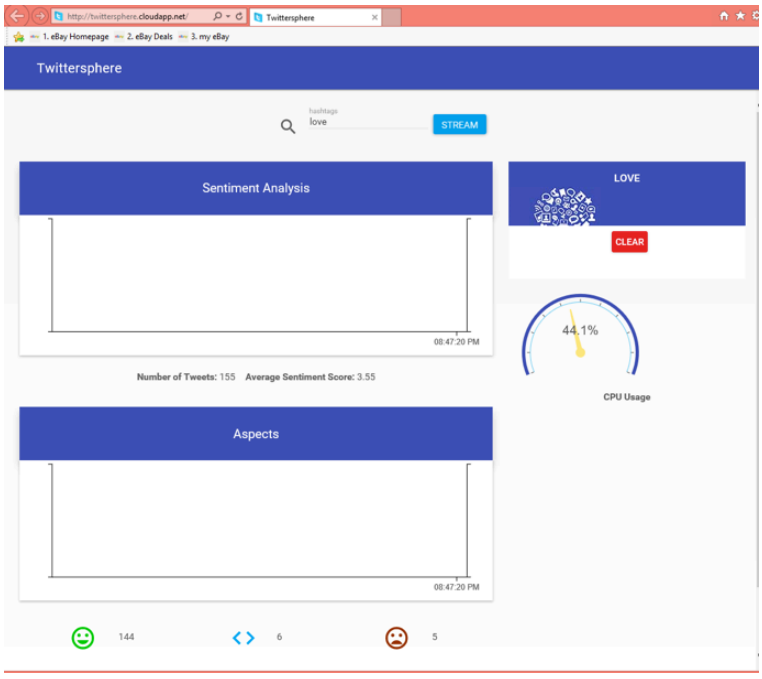
Appendix E Figure 4: Browser compatibility (Chrome)

Browser Compatibility (Firefox)



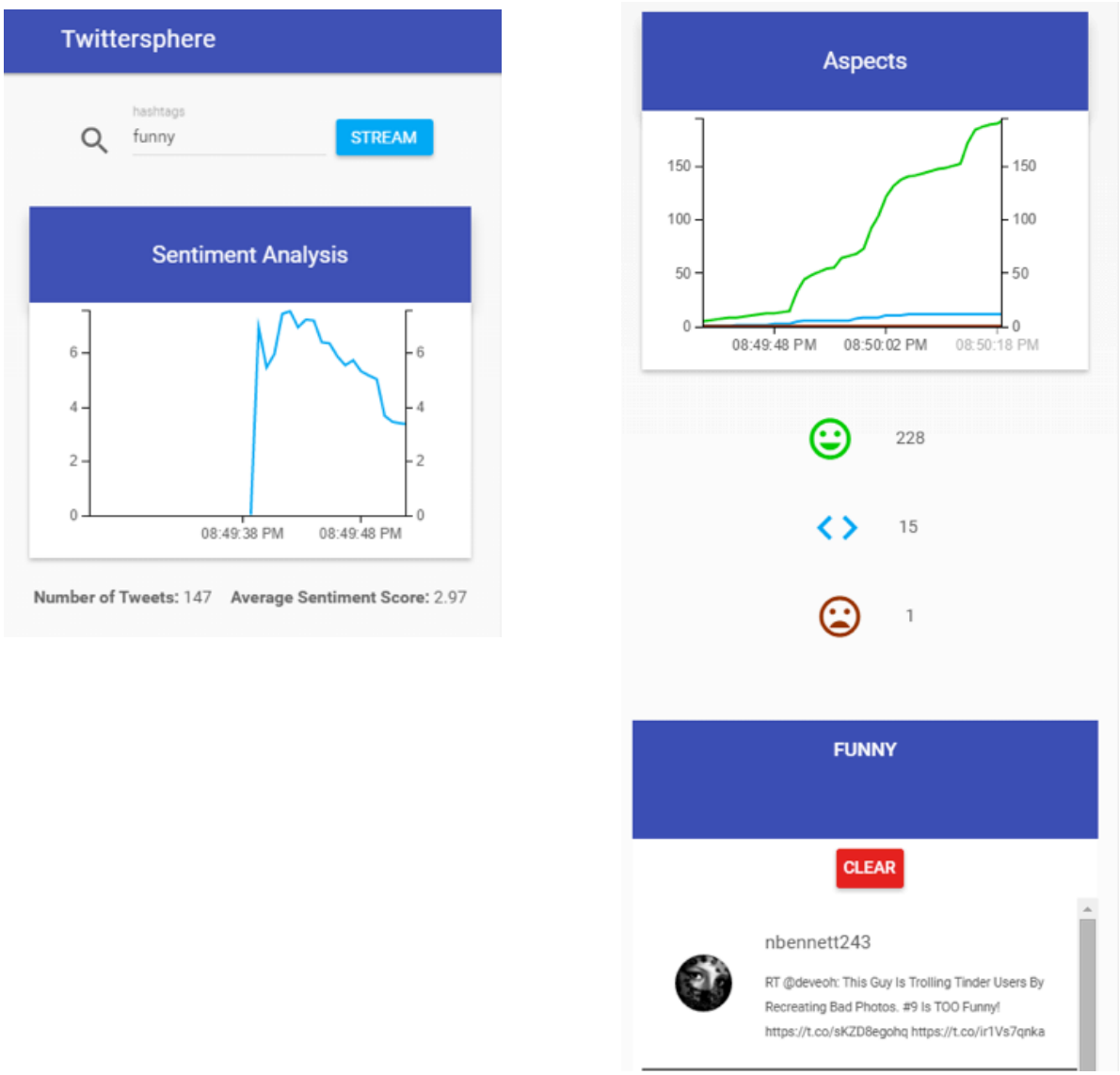
Appendix E Figure 5: Browser compatibility (Firefox)

Browser Compatibility (IE)



Appendix E Figure 6: Browser compatibility (IE)

Responsive Design



Appendix E Figure 7: Responsive design