1 ABSTRACT
In this paper we describe a system for real-time sentiment estimate and analysis on Reddit, a social news aggregation, web content rating, and discussion website. Reddit has become a unique venue where rich interpersonal interaction takes place in the form of online conversations. Sentiment analysis can help explore how people react to specific topics, news and events. We have developed a Chrome extension for people to see and understand readers’ emotional reactions by extracting, aggregating, and visualizing sentiment properties embedded in the text data. This system delivers results instantly, so that people can understand public opinion and emotions in real time when browsing Reddit.

1.1 Author Keywords
Data Visualization, sentiment analysis, natural language processing, social network

2 INTRODUCTION
Reddit allows users to engage in conversations from anywhere on any topic ranging from art, holidays to the presidential election. We can draw useful insights, if we are able to see and understand the large amount of text data efficiently through visualization. However, the high dimensionality of text data poses a challenge in data visualization. Moreover, providing relevant context to aid the understanding of the visualization in side of the existing Reddit UI can be difficult.

Therefore, we decided to extract sentiments from the text data first and then build a visualization based on the extraction. The sentiment visualization can be useful in my real-world applications. For example, we can improve the quality of a product based on the sentiment analysis results on relevant customer opinions on Reddit. This type of real-time market feedback is helpful for products and service with short lifetime, like consumer electronics, which traditional market feedback loop is not fast enough for product iteration. Moreover, the sentiment analysis results can be helpful to make predictions on events like presidential election and regional violence.

In order to achieve these goals, our system consists of four main functions:
1) Extract sentiments from given text or a single Reddit URL and return the scores on five emotion dimensions: joy, sad, disgust, anger, fear.
2) Analyze and aggregate emotions on a collection of Reddit threads
3) Filter posts by the magnitude of emotions
4) Redirect users from the emotion analysis result to relevant Reddit thread.

Further evaluation by experts in the industry and academia confirmed that the system yielded meaningful results.

3 RELATED WORK

Research that explores temporal and geographical based sentiment analysis to visualize differences in sentiments among news sources. Provides the useful foundation for building GUI’s that display sentiment analysis over multiple emotional dimensions instead of the polar positive and negative scale. Also provides groundwork for dealing with aggregation of sentiment analysis data into useful visualizations.


Research that uses k-means clustering over sentiment analysis data to group forums and identify “hotspots”. A very interesting discussion on how to aggregate forums and threads based on sentiment analysis data.

Research that explores relationship between MooCs discussion forums and attrition rates of the course. Findings show poor results of correlation. Interesting because they use a basic sentiment analysis of positive and negative and reinforce that using a multidimensional system could lead to more salient results.


Research that explores how irony affects sentiment analysis. The article found that irony is often used in conjunction with a seemingly positive statement to reflect a negative one, but rarely is it the other way around. We could use this heuristic to adjust for possibly extremely ironic posts, as are commonly found on reddit.

3.5 Wexler, Steve. How to Visualize Sentiment and Inclination [5].

Research explores the best practices for visualizing people’s sentiments and tendencies using either a Likert Scale or a Net Promoter Score (NPS). The conclusion is that in most cases, a diverging stacked bar chart is the best to see survey responses that involves sentiments and tendencies.

3.6 Healey, Ramaswamy. Visualizing Twitter Sentiment [6].

Research that studies ways to estimate and visualize sentiment of tweets posted on Twitter, an online social network that allows users to upload short text messages—tweets—of up to 140 characters. Twitter has also shown the potential for societal impact, for example, in its use as a communication and organizing tool for activists during the 2011 "Arab Spring" protests in various Middle Eastern countries.

4 METHODS

Sentiment is defined as "an attitude, thought, or judgment prompted by feeling". For extracting emotions from the text, we use IBM Watson AlchemyAPI's sentiment analysis API. Different from traditional bipolar sentiment scales, IBM Watson APIs provide non-normalized scores on five different emotion dimensions, including joy, sad, anger, fear and disgust. We made an intentional choice to use this API tool kit because the numeric result is closer to real human feelings. A person can feel multiple feelings at the same time, and the magnitude of emotions can vary under different circumstances. It also helps understand why people feel in certain way. For example, when customers are unsatisfied with a product, the vendor usually wants to have insights of granularity instead of just the fact that customers give negative reviews. A chrome extension implements the interactive components of our service, such as text highlighting, url selection, and a button to aggregate a page. A node.js server is hosted on EC-2 that processes the content and returns back JSON data and an interactive D3 visualization. The system allows individuals to explore the topics that interest them. The application can be used in any user-defined scope of texts or threads and it returns the result in real time.

4.1 Highlight Text

A user can highlight text in any web page, right click and select the Analyze Highlighted Text (see Figure 1) option from the context menu.

Figure 1. Analyze Highlighted Text option in Chrome right-click menu

The highlighted text will be analyzed and a bar chart of the emotions will be generated and displayed in a pop up menu (see figure 2).
4.2 URL Analysis
A user can right click on a link in any web page and select the Analyze URL’s Contents Text (see Figure 3) option from the context menu. The URL will be mined for text and a bar chart of the emotions will be generated and displayed in a pop up menu similar to highlighting text (see Figure 2).

If there is not enough amount of text to conduct sentiment analysis in the main body of the page, the system will use the comments instead. Similar to the highlighting text feature, the entire page will be analyzed and the emotion analysis result will be displayed on a bar chart.

4.3 Page Aggregation (Reddit only)
A user can right click on any Reddit subreddit or the front page and select Aggregate Analysis over all posts (see Figure 4).

Our system will then mine any number of links from the top posts by first checking if the links are an external article and then mining that text or in the case of pictures and gifs, mine the comments related to the pictures and gifs in the reddit thread. The aggregation will be mined for emotional analysis data and a sortable diverging stacked bar chart (see Figure 5) visualization will be returned.

We decided to display the visualization dashboard in a separated window because we don’t want to misguide the users by skewing the original text data. Moreover, the user can further drill down by filtering the result in any of the five emotions. Once the result is sliced, the user will see a sorted bar chart (see Figure 6) with the link with the strongest emotion on the top. Then the user can browse the links by clicking on the bar chart to be transported to the page.
5 RESULTS

In this section, we are going to break down the evaluation of our system by the three major features.

5.2 Running time
Running time is important for any real time tool. The faster the tool runs the better the engagement and the stronger sense of responsiveness. We ran our tool 10 times per feature and took an average of the running time.

5.2.1 Highlight Text
Running sentiment analysis on text that spans 3 - 4 paragraphs or less usually takes an average of .6 seconds.

5.2.2 URL Analysis
Mining a URL for text and running sentiment analysis on the text takes an average of 2 seconds.

5.2.3 Aggregation (Reddit only)
Mining an aggregation of a page and running a batch sentiment analysis of the top 15 entries takes an average of 40 seconds. 20 entries takes an average of 60 seconds.

5.2 User Feedback
We asked the following questions to users and asked them to respond on a scale of 1-10. 1 being strongly disagree and 10 being strongly agree. We got responses from 23 participants. The results shown below are the mean of the scores for each question.

1) I find it is useful to see and understand the emotions embedded in text data.
   - Results: 8.39

2) I like right clicking to interact with my page, link, or highlighted text
   - Results: 9.26

3) For a single URL or highlighting text, the distribution of emotions matched what I expected?
   - Results: 6.52

4) When browsing based on sorted emotions, does the link representing the highest value of emotion...
accurately match the article that I think has the highest value of that emotion in the aggregation.
   - Results: 7.56

5) I find the visualization dashboard is easy to understand.
   - Results: 8.56

6) I’m able to answer the questions I have by using the data visualization tool.
   - Results: 7.69

7) I find the tool delightful to use.
   - Results: 8.04

6 DISCUSSION
When collected feedback during the poster session, most of our testing users found the system very useful in use cases when they are looking for a cheerful reading to lift their mood, or when they want dive into a heated discussion and figure out what people are arguing about. Ms. Chen Zhao, a researcher working in ecommerce validated our assumption that this system will be very useful for understanding product reviews. She said that the bipolar sentiment analysis tool her company is currently using is not sufficient for understanding why customers are satisfied or unsatisfied with their products and how they can improve in the future. She needs a business analytics tool similar to our system that can give multi-dimensional sentiment analysis in real-time.

Our users also like the functionality of drilling down into threads level by level by jumping to a link directly from the visualization and then conducting more granular visualization on the new page. This functionality works better than the build-in search on Reddit because our systems helps them find the thread they have in mind without any prior knowledge about the content. Some user suggested that he would like to see what exactly causes the strong emotion in the visualization when he is tracing back to a link from the bar chart. Having the ability to track back will help users understand the relationships between text data and the highly summarized visualization better.

We also got positive feedback on the usability of the system. Users like that the sentiment analysis functionality is built into the right-click menu of Chrome, so that it is accessible from anywhere. Moreover, the diverging stacked bar chart is easy to read with center alignment and a color palette with distinguishable colors.

In the aggregation visualization, users tended to enjoy browsing articles on various spectrums of emotions. Some engaged with the most “joyful” articles while others engaged with the most negative articles. From non formalized observation, this tool has potential to enable a new form of browsing.

The running time for the single URL mining and text highlight was definitely acceptable. The Watson API did not allow us to batch sentiment analysis calls, and there is extra overhead to mining and aggregating top links from reddit that involves an API call to Reddit’s API. We added a loading spinner (see Figure 7) to the aggregate view so users at least knew that they had correctly called the aggregation functions. When we didn't have it, users would repeatedly call the aggregate function, expecting immediate results.

![Please wait while we process the content](image)

Figure 7. Loading spinner and message when generating an aggregated emotion analysis chart

The IBM Watson APIs used in the system does not return desireable result in many cases on Reddit. Different from a news site or academic publications where formal written language is usually used, Reddit threads tend to have more conversational language. Moreover, the Internet is highly ironic, uses doubletalk, and often tries to be humorous. We have observed that IBM Watson APIs do not have good performance when the text contains sarcasm, puns, Internet originated words, etc.

Below is an example (see Figure 8) where the IBM Watson APIs don’t return desirable results. The discussion on “make appearances at non-profit and community events as
The Grinch” is supposed to be funny, but the result returned by the APIs is dominated by fear (see Figure 9). It is impressive the APIs captured the cultural reference to “The Grinch”, “Krampus” and “Scrooge” and thereby generated a high score on fear. However, it missed the irony of the thread.

![Image](image.png)

Figure 8. Reddit thread on “I make appearances at non-profit and community events as The Grinch”

![Image](image.png)

Figure 9. Emotion analysis result where fear dominates

7 FUTURE WORK
While we have received many positive feedback from experts from academia and industry, we also heard some very useful suggestions and feature requests.

7.1 Multi-facet filter
As mentioned previously, a person can have multiple emotions at the same time. Enabling users to filter and sort the results in multiple facets will be useful for many use cases that involve multiple emotions at the same time.

7.2 Runtime improvement
Currently, analysing and aggregating 20 Reddit threads takes about 60 seconds before the user gets the result. The long runtime disrupts the flow of drilling down into the text level by level, which can cause the user to lose her attention during the task. In the future, we want to reduce the runtime of the aggregating system by building our own sentiment analyzer that can better handle parallel calls to analysis. The Watson API doesn’t allow for batch calls for sentiment analysis, most likely to increase number of calls per use for charging developers. We also made our calls to the API synchronous to ensure that all the threads would finish before creating the d3 visualization. We can improve runtime by making better use of the asynchronous features of Javascript and D3 graph making.

7.3 Extend aggregation feature to all websites
There are many other text-rich sites like Reddit, such as news aggregators, web content rating, and discussion forums. Currently, only our text highlighter is compatible with non-Reddit websites. In the future, we want to integrate the aggregator with most major websites.

7.4 Trace back to text data
Users want the system to highlight the sections of the text that contribute to the strong emotions, so that they can understand the causation of the high emotion scores better. One possible solution is to highlight the original text with the color associated with the emotion in the bar chart and adjust the font size according to the magnitude of the emotion. However, such implementation might decrease the readability of the original text. In the case where multiple emotions collide on the same section of text, the visual representation could be confusing.

7.5 Improve language model and sentiment evaluation
As mentioned in discussion, the IBM Watson APIs are the not ideal model for sentiment analysis on Reddit. In order to solve the problem, we will need to implement custom backend for sentiment and emotional analysis. A new emotion analysis backend should be created to account for the specific challenges of user created text on the internet as the Watson API is optimized for professional text [4].

7.6 Track emotional trend over time
Some user requested the feature to track how the emotions about the topic change over time. It can be useful to understand how people’s feeling change when an event involves or when a new product is released. However, our current system doesn’t allow us to actively query all Reddit URLs and index the result over time.

7.7 Track individual user behavior
Some user suggested we could use the application to track the emotional state of a particular user by regularly checking the emotion scores of the posts generated by this user. This functionality can be useful for identifying misbehaved users through traits like extreme emotional swings or being angry all the time. Thereby, the administrator of the community can remove can remove these users after verification. However, such functionality is controversial because it can be interpreted as censoring free speech.
REFERENCES