A System for Real-time Twitter Sentiment Analysis of 2012 U.S. Presidential Election Cycle

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Abstract

This paper describes a system for real-time analysis of public sentiment toward presidential candidates in the 2012 U.S. election as expressed on Twitter, a micro-blogging service. Twitter has become a central site where people express their opinions and views on political parties and candidates. Emerging events or news are often followed almost instantly by a burst in Twitter volume, providing a unique opportunity to gauge the relation between expressed public sentiment and electoral events. In addition, sentiment analysis can help explore how these events affect public opinion. While traditional content analysis takes days or weeks to complete, the system demonstrated here analyzes sentiment in the entire Twitter traffic about the election, delivering results instantly and continuously. It offers the public, the media, politicians and scholars a new and timely perspective on the dynamics of the electoral process and public opinion.

1 Introduction

Social media platforms have become an important site for political conversations throughout the world. In the year leading up to the November 2012 presidential election in the United States, we have developed a tool for real-time analysis of sentiment expressed through Twitter, a micro-blogging service, toward the incumbent President, Barack Obama, and the nine republican challengers - four of whom remain in the running as of this writing. With this analysis, we seek to explore whether Twitter provides insights into the unfolding of the campaigns and indications of shifts in public opinion.

Twitter allows users to post tweets, messages of up to 140 characters, on its social network. Twitter usage is growing rapidly. The company reports over 100 million active users worldwide, together sending over 250 million tweets each day (Twitter, 2012). It was actively used by 13% of on-line American adults as of May 2011, up from 8% a year prior (Pew Research Center, 2011). More than two thirds of U.S. congress members have created a Twitter account and many are actively using Twitter to reach their constituents (Lassen & Brown, 2010; TweetCongress, 2012). Since October 12, 2012, we have gathered over 36 million tweets about the 2012 U.S. presidential candidates, a quarter million per day on average. During one of the key political events, the Dec 15, 2011 primary debate in Iowa, we collected more than half a million relevant tweets in just a few hours. This kind of 'big data' vastly outpaces the capacity of traditional content analysis approaches, calling for novel computational approaches.

Most work to date has focused on post-facto analysis of tweets, with results coming days or even months after the collection time. However,
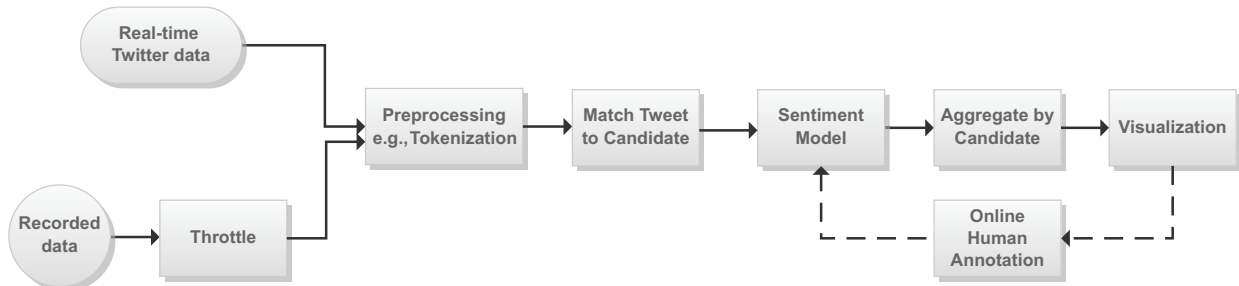
Figure 1. The system architecture for real-time processing Twitter data

because tweets are short and easy to send, they lend themselves to quick and dynamic expression of instant reactions to current events. We expect automated real-time sentiment analysis of this user-generated data can provide fast indications of changes in opinion, showing for example how an audience reacts to particular candidate's statements during a political debate. The system we present here, along with the dashboards displaying analysis results with drill-down ability, is precisely aimed at generating real-time insights as events unfold.

Beyond the sheer scale of the task and the need to keep up with a rapid flow of tweets, we had to address two additional issues. First, the vernacular used on Twitter differs significantly from common language and we have trained our sentiment model on its idiosyncrasies. Second, tweets in general, and political tweets in particular, tend to be quite sarcastic, presenting significant challenges for computer models (González-Ibáñez et al., 2011). We will present our approaches to these issues in a separate publication. Here, we focus on presenting the overall system and the visualization dashboards we have built. In section 2, we begin with a review of related work; we then turn in section 3 to a description of our system's architecture and its components (input, preprocessing, sentiment model, result aggregation, and visualization); in sections 4 and 5 we evaluate our early experience with this system and discuss next steps.

2   Related Work

In the last decade, interest in mining sentiment and opinions in text has grown rapidly, due in part to the large increase of the availability of documents and messages expressing personal opinions (Pang & Lee, 2008). In particular, sentiment in Twitter data has been used for prediction or measurement in a variety of domains, such as stock market, politics and social movements (Bollen et al., 2011;

Choy et al., 2011; Tumasjan et al., 2010; Zeitzoff, 2011). For example, Tumasjan (2010) found tweet volume about the political parties to be a good predictor for the outcome of the 2009 German election, while Choy et al. (2011) failed to predict with Twitter sentiment the ranking of the four candidates in Singapore's 2011 presidential election.

Past studies of political sentiment on social networks have been either post-hoc and/or carried out on small and static samples. To address these issues, we built a unique infrastructure and sentiment model to analyze in real-time public sentiment on Twitter toward the 2012 U.S. presidential candidates. Our effort to gauge political sentiment is based on bringing together social science scholarship with advanced computational methodology: our approach combines real-time data processing and statistical sentiment modeling informed by, and contributing to, an understanding of the cultural and political practices at work through the use of Twitter.

3   The System

For accuracy and speed, we built our real-time data processing infrastructure on the IBM's InfoSphere Streams platform (IBM, 2012), which enables us to write our own analysis and visualization modules and assemble them into a real-time processing pipeline. Streams applications are highly scalable so we can adjust our system to handle higher volume of data by adding more servers and by distributing processing tasks. Twitter traffic often balloons during big events (e.g. televised debates or primary election days) and stays low between events, making high scalability strongly desirable. Figure 1 shows our system's architecture and its modules. Next, we introduce our data source and each individual module.

3.1 Input/Data Source

We chose the micro-blogging service Twitter as our data source because it is a major source of online political commentary and discussion in the U.S. People comment on and discuss politics by posting messages and 're-tweeting' others' messages. It played a significant role in political events worldwide, such as the Arab Spring Movement and the Moldovian protests in 2009. In response to events, Twitter volume goes up sharply and significantly. For example, during a republican debate, we receive several hundred thousand to a million tweets in just a few hours for all the candidates combined.

Twitter's public API provides only 1% or less of its entire traffic (the "firehose"), without control over the sampling procedure, which is likely insufficient for accurate analysis of public sentiment. Instead, we collect all relevant tweets in real-time from the entire Twitter traffic via Gnip Power Track, a commercial Twitter data provider. To cope with this challenge during the later stages of the campaign, when larger Twitter traffic is expected, our system can handle huge traffic bursts over short time periods by distributing the processing to more servers, even though most of the times its processing load is minimal.

Since our application targets the political domain (specifically the current Presidential election cycle), we manually construct rules that are simple logical keyword combinations to retrieve relevant tweets – those about candidates and events (including common typos in candidate names). For example, our rules for Mitt Romney include *Romney, @MittRomney, @PlanetRomney, @MittNews, @believeinromney, #romney, #mitt, #mittromney, and #mitt2012*. Our system is tracking the tweets for nine Republican candidates (some of whom have suspended their campaign) and Barack Obama using about 200 rules in total.

3.2 Preprocessing

The text of tweets differs from the text in articles, books, or even spoken language. It includes many idiosyncratic uses, such as emoticons, URLs, *RT* for re-tweet, @ for user mentions, # for hashtags, and repetitions. It is necessary to preprocess and normalize the text.

As standard in NLP practices, the text is tokenized for later processing. We use certain rules to handle the special cases in tweets. We compared several Twitter-specific tokenizers, such as TweetMotif (O'Connor et al., 2010) and found Christopher Potts' basic Twitter tokenizer best suited as our base. In summary, our tokenizer correctly handles URLs, common emoticons, phone numbers, HTML tags, twitter mentions and hashtags, numbers with fractions and decimals, repetition of symbols and Unicode characters (see Figure 2 for an example).

3.3 Sentiment Model

The design of the sentiment model used in our system was based on the assumption that the opinions expressed would be highly subjective and contextualized. Therefore, for generating data for model training and testing, we used a crowd-sourcing approach to do sentiment annotation on in-domain political data.

To create a baseline sentiment model, we used Amazon Mechanical Turk (AMT) to get as varied a population of annotators as possible. We designed an interface that allowed annotators to perform the annotations outside of AMT so that they could participate anonymously. The Turkers were asked their age, gender, and to describe their political orientation. Then they were shown a series of tweets and asked to annotate the tweets' sentiment (positive, negative, neutral, or unsure), whether the tweet was sarcastic or humorous, the sentiment on a scale from positive to negative, and the tweet author's political orientation on a slider scale from conservative to liberal. Our sentiment model is based on the sentiment label and the sarcasm and humor labels. Our training data consists of nearly 17000 tweets (16% positive, 56% negative, 18% neutral, 10% unsure), including nearly 2000 that were multiply annotated

Tweet	WAAAAAH!!! RT @politico: Romney: Santorum's 'dirty tricks' could steal Michigan: http://t.co/qEns1Pmi #MIprimary #tcot #teaparty #GOP
Tokens	WAAAAAH !!! RT @politico : Romney : Santorum's ' dirty tricks ' could steal Michigan : http://politi.co/wYUz7m #MIprimary #tcot #teaparty #GOP

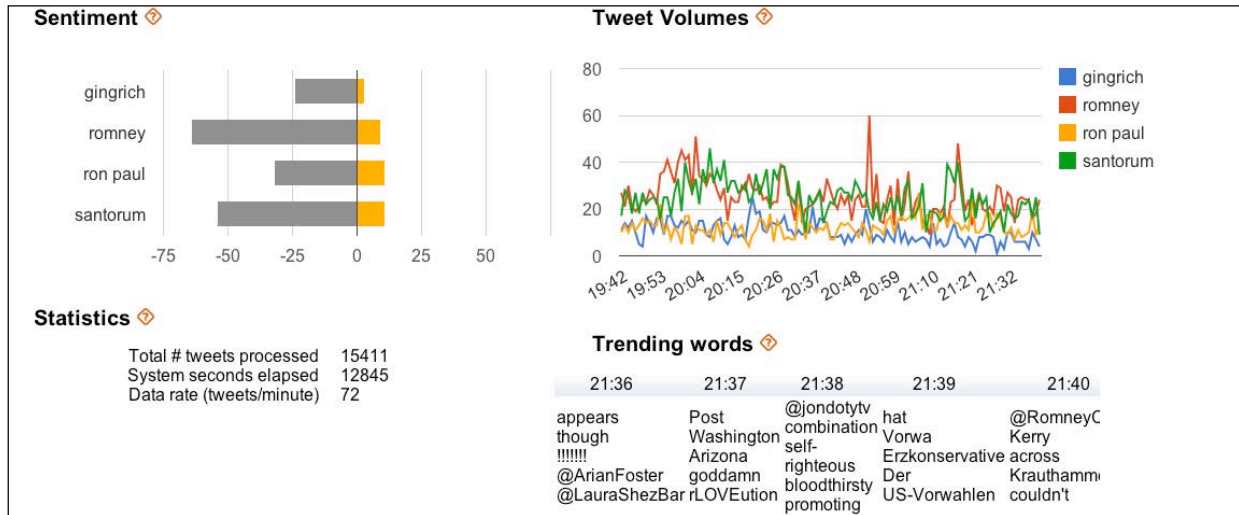Figure 2. The output tokens of a sample tweet from our tokenizer

Figure 3. Dashboard for volume, sentiment and trending words

to calculate inter-annotator agreement. About 800 Turkers contributed to our annotation.

The statistical classifier we use for sentiment analysis is a naïve Bayes model on unigram features. Our features are calculated from tokenization of the tweets that attempts to preserve punctuation that may signify sentiment (e.g., emoticons and exclamation points) as well as twitter specific phenomena (e.g., extracting intact URLs). Based on the data we collected our classifier performs at 59% accuracy on the four category classification of negative, positive, neutral, or unsure. These results exceed the baseline of classifying all the data as negative, the most prevalent sentiment category (56%). The choice of our model was not strictly motivated by global accuracy, but took into account class-wise performance so that the model performed well on each sentiment category.

3.4 Aggregation

Because our system receives tweets continuously and uses multiple rules to track each candidate's tweets, our display must aggregate sentiment and tweet volume within each time period for each candidate. For volume, the system outputs the number of tweets every minute for each candidate. For sentiment, the system outputs the number of *positive*, *negative*, *neutral* and *unsure* tweets in a sliding five-minute window.

3.5 Display and Visualization

We designed an Ajax-based HTML dashboard (Figure 3) to display volume and sentiment by candidate as well as trending words and system statistics. The dashboard pulls updated data from a web server and refreshes its display every 30 seconds. In Figure 3, the top-left bar graph shows the number of positive and negative tweets about each candidate (right and left bars, respectively) in the last five minutes as an indicator of sentiment towards the candidates. We chose to display both positive and negative sentiment, instead of the difference between these two, because events typically trigger sharp variations in both positive and negative tweet volume. The top-right chart displays the number of tweets for each candidate every minute in the last two hours. We chose this time window because a live-broadcast primary debate usually lasts about two hours. The bottom-left shows system statistics, including the total number of tweets, the number of seconds since system start and the average data rate. The bottom-right table shows trending words of the last five minutes, computed using TF-IDF measure as follows: tweets about all candidates in a minute are treated as a single "document"; trending words are the tokens from the current minute with the highest TF-IDF weights when using the last two hours as a corpus (i.e., 120 "documents"). Qualitative examination suggests that the simple TF-IDF metric effectively identifies the most prominent words when an event occurs.

The dashboard gives a synthetic overview of volume and sentiment for the candidates, but it is often desirable to view selected tweets and their sentiments. The dashboard includes another page

Overall Tweet Volumes

Sentiment	Most negative tweets
-97.6	@ROCKWITHBECK @NewtGingrich @MittRomney So you're stooping to leftist tactic by *trying* to make fun of looks? Gingrich is has more heart.
-97.1	RT @PoliticallyOC: #Santorum is such a hypocrite. He endorses Romney, then bashes him when it's to his advantage. Just like he did as se ...
-96.6	From living in Illinois for about a decade, I'd be pretty surprised if it swung Santorum's way. He should get southern counties but not Chg.
-95.3	what pisses me off is romney had already been CHOSEN for us before the friggin primaries even started, like we have no say #justsayno2mitt

Sentiment	Most positive tweets
94	@cdc444 Every time Santorum makes less than 60% of the delegates, he's losing and Romney's gaining on him.
92.4	@DwyaneWade @RonPaul @MelMajik9 @McllroyRory #endthefed buy silver as soon as the correction comes watch for it #NWO #RonPaulRevolution
90	RT @LibertyTakeover: Congratulations to #ronpaul for his first victory! @ronpaul won the popular vote in the Virgin Islands today! @Judg ...
87	We need to listen to this man. His logic & analysis is impeccable. "Thomas Sowell: Only Gingrich has right stuff" http://t.co/1G9QZwzl

Sentiment	Random neutral tweets and your tweets
0	It appears as though Mitt Romney is the man to challenge Obama. That said it also appears as though the election shall be a crapshoot.
0	RT @princesspeachok: i hope rick santorum drops his eyeshadow palette and his favorite shade crumbles from the impact
0	Santorum wins Kansas caucuses, Romney wins Wyoming – Washington Post http://t.co/LLmLbdq1
0	Santorum wins Kansas caucuses, Romney wins Wyoming – Washington Post http://t.co/7Sol6VaU

Tag Cloud

#KONY2012 #Mitt2012 #Newt2012 #OWS #RonPaul #RonPaul2012 #Santorum #fraud #gop #ronpaul #tcot . ... 2012 >>> @BorowitzReport @MittRomney @NewtGingrich @RickSantorum @RomneyCentral Caucus County Der Erzkonservative GOP Gingrich Guam Islands Kansas Mitt Newt Obama Paul President Rechtsau Republican Rick Romney Ron Santorum Santorum's Spiel US-Vorwahlen Virgin Vorwa Wins Wyoming candidate
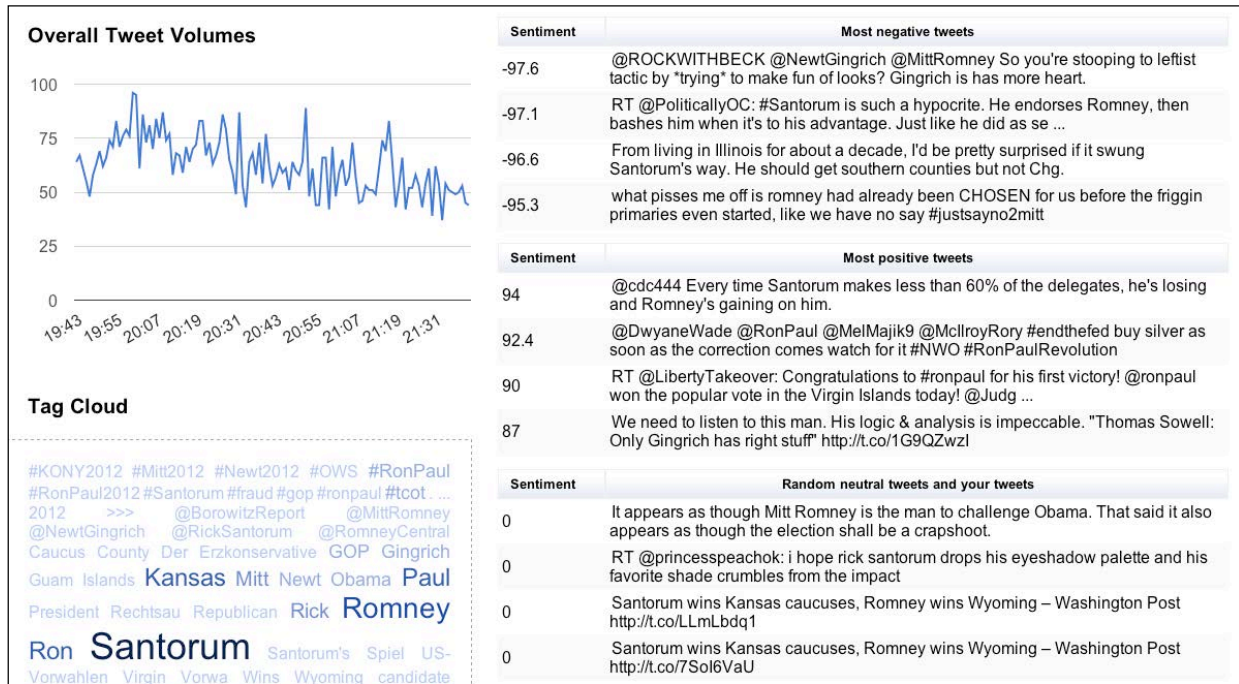
Figure 5. Dashboard for most positive, negative and frequent tweets

(Figure 4) that displays the most positive, negative and frequent tweets, as well as some random neutral tweets. It also shows the total volume over time and a tag cloud of the most frequent words in the last five minutes across all candidates. Another crucial feature of this page is that clicking on one of the tweets brings up an annotation interface, so the user can provide his/her own assessment of the sentiment expressed in the tweet. The next section describes the annotation interface.

3.6   Annotation Interface

The online annotation interface shown in Figure 5 lets dashboard (Figure 4) users provide their own judgment of a tweet. The tweet's text is displayed at the top, and users can rate the sentiment toward the candidate mentioned in the tweet as *positive*, *negative* or *neutral* or mark it as *unsure*. There are also two options to specify whether a tweet is *sarcastic* and/or *funny*. This interface is a simplified version of the one we used to collect annotations from Amazon Mechanical Turk so that annotation can be performed quickly on a single tweet. The online interface is designed to be used while watching a campaign event and can be displayed on a tablet or smart phone.

The feedback from users allows annotation of recent data as well as the ability to correct misclassifications. As a future step, we plan to establish an online feedback loop between users and the sentiment model, so users' judgment serves to train the model actively and iteratively.

4   System Evaluation

In Section 3.3, we described our preliminary sentiment model that automatically classifies tweets into four categories: positive, negative, neutral or unsure. It copes well with the negative bias in political tweets. In addition to evaluating

Figure 4. Online sentiment annotation interface

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the model using annotated data, we have also begun conducting correlational analysis of aggregated sentiment with political events and news, as well as indicators such as poll and election results. We are exploring whether variations in twitter sentiment and tweet volume are predictive or reflective of real-world events and news. While this quantitative analysis is part of ongoing work, we present below some quantitative and qualitative expert observations indicative of promising research directions.

One finding is that tweet volume is largely driven by campaign events. Of the 50 top hourly intervals between Oct 12, 2011 and Feb 29, 2012, ranked by tweet volume, all but two correspond either to President Obama's State of the Union address, televised primary debates or moments when caucus or primary election results were released. Out of the 100 top hourly intervals, all but 18 correspond to such events. The 2012 State of the Union address on Jan 24 is another good example. It caused the biggest volume we have seen in a single day since last October, 1.37 million tweets in total for that day. Both positive and negative tweets for President Obama increased three to four times comparing to an average day.

During the Republican Primary debate on Jan 19, 2012 in Charleston, NC one of the Republican candidates, Newt Gingrich, was asked about his ex-wife at the beginning of the debate. Within minutes, our dashboard showed his negative sentiment increase rapidly – it became three times more negative in just two minutes. This illustrates how tweet volume and sentiment are extremely responsive to emerging events in the real world (Vergeer et al., 2011).

These examples confirm our assessment that it is especially relevant to offer a system that can provide real-time analysis during key moments in the election cycle. As the election continues and culminates with the presidential vote this November, we hope that our system will provide rich insights into the evolution of public sentiment toward the contenders.

5   Conclusion

We presented a system for real-time Twitter sentiment analysis of the ongoing 2012 U.S. presidential election. We use the Twitter "firehose" and expert-curated rules and keywords to get a full and accurate picture of the online political landscape. Our real-time data processing infrastructure and statistical sentiment model evaluates public sentiment changes in response to emerging political events and news as they unfold. The architecture and method are generic, and can be easily adopted and extended to other domains (for instance, we used the system for gauging sentiments about films and actors surrounding Oscar nomination and selection).

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