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Completed Research Paper

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Abstract

Internet of Things (IoT) is an increasingly important technology. Understanding the attitudes toward IoT may provide insights into the future development and management of IoT and the management of online platforms. In this paper, we examine online platform users' attitudes toward IoT, by analysing Twitter data. We analyse the backgrounds of Twitter users associated with different attitudes, including the frequency of using Twitter and the geographical location of posts (i.e., called "tweets"). The research findings suggest that most tweets reflect positive attitudes toward IoT and concentrate on information technologies. Some users expressed concerns with security and privacy issues. Most Twitter users surveyed come from coastal areas of the USA.

Keywords: Internet of Things, Twitter data, Content analysis, individual attitude

Introduction

With the development of technology and smart devices, there is an increasing demand of ubiquitous context-aware platforms that support an interconnected, heterogeneous, and distributed network of devices (Khodadadi, Dastjerdi and Buyya 2017). Internet of Things (IoT) refers to an interconnected, heterogeneous, and distributed network of devices. In 1999, the term "Internet of Things" was first used by Kevin Ashton during a presentation on supply-chain management. He proposed this term to extend RFID (radio frequency identification devices) and sensor networks technology into objects used in daily life. The definition of IoT was subsequently extended; people, process, data, and things were included in the definition of IoT. Moreover, Industrial IoT (IIoT) extends IoT to perform specific tasks of machines such as machine to machine (M2M) communication (Martinez et al. 2017). Recently, the notions of "object smartness" and "network smartness" were used to distinguish IoT from similar concepts like "sensor networks".

Even though the concept of IoT is improving, there are also issues associated with IoT, such as security breach, a lack of regulations, incompatibility between different devices, and short device lifespan. Among those issues, security breach is one of the most critical ones; IoT has a high probability to be attacked and hacked (Oweis et al. 2017). Given those issues, people have different attitudes toward IoT. It is thus useful to identify how people think about IoT. Investigating attitudes toward IoT will be valuable to understand potential problems and policy implications associated with IoT. This will further facilitate the development and use of IoT in societies.

A number of approaches are used to understand attitudes, such as telephone surveys and face-to-face interviews. This paper analyses attitudes toward IoT by examining data from IT platforms. In particular, we collected and analysed data from Twitter. Twitter is the largest IT platform and allows users to

publish short texts with each text up to 140 characters. These texts are called "tweets". Tweets provide rich information about users' opinions and thoughts. By publishing tweets, users can interact with each other, such as daily chatter, conversations, sharing information, and reporting news (Li and Goodchild 2013).

As "an individual's favourable or unfavourable attitude toward an object, institution, or event can be inferred from verbal or nonverbal responses toward the object, institution, or event in question" (Ajzen 2005 p. 5), we consider tweets about IoT as representative of users' attitudes toward IoT. Therefore, by analysing tweets, we can infer users' attitudes toward IoT. When Twitter users post tweets about IoT, a sequence of other behaviours are triggered, such as reply, forwarding texts (or retweets), and sharing locations. By examining those other behaviours, we can better understand attitudes toward IoT.

This paper aims to understand attitudes toward IoT through content analysis of tweets. We address the following research questions:

(1) What are the patterns of attitudes toward IoT?

(2) Do users with different frequency of using IT platform or from different geographical locations have different attitudes toward IoT?

The analysis of this paper offers several insights. The findings indicate that most Twitter users have positive attitudes toward IoT. In particular, positive attitudes are often associated with the technologies of IoT; negative attitudes are often associated with security and privacy issues of IoT. Additionally, Twitter users are interested in the development of IoT. Usage frequency of Twitter has little influence on attitudes toward IoT, but has significant impact on the topics related to IoT. Geographical locations have relatively more influence on attitudes toward IoT.

Literature Review

Internet of Things

The applications of Internet of Things (IoT) are commonplace, such as smart home networks (Ukil and Bandyopadhyay 2014). The IoT applications can be classified into four domains – transportation and logistics domain, healthcare domain, smart environment, and personal and social domain (Atzori and Iera 2010).

Previous findings reveal that the individual attitude toward IoT is primarily positive (e.g. Bian et al. 2016). Public concerns around IoT are related to privacy and security issues (Atzori, Iera, and Morabito, 2010). The literature has thus examined privacy and security issues related to IoT from different perspectives, such as conceptual analysis (e.g. Conti et al. 2018) and trust management (e.g. Yan and Zhang 2014).

Attitudes toward IoT

Individuals may respond favourably or unfavourably to object, institution, or event with their attitude (Ajzen 2005). The evaluative nature determines the characteristic of attitude (Ajzen 2005). It is impossible to observe attitude directly; attitude can only be inferred from behaviours (Ajzen 2005).

Attitude is an important concept in behavioural research and a key antecedent of behavioural intention (Ajzen and Fishbein 1977). Existing studies measure attitude in different ways, such as analysing attitude toward knowledge sharing from anticipated extrinsic rewards, anticipated reciprocal relationships, and sense of self-worth (Bock et al. 2005), analysing attitude toward IT adoption from behavioural beliefs (e.g. image, ease of use, compatibility, and so forth) (Karahanna and Straub 1999), and investigating attitude toward voice and electronic mail technology from psychometric properties (Adams and Nelson 1992).

IT platforms may provide a source to observe people's attitudes toward IoT. One advantage is that IT platforms have a large data set. Another advantage is that data from IT platforms is relatively objective, in comparison with other approaches such as surveys.

While researchers have evaluated attitudes toward IoT through Twitter trends and Google trends (Bian et al. 2016), they did not consider users' backgrounds. To gain a deeper understanding of attitudes

toward IoT, it is important to analyse whether users with different backgrounds, such as usage frequency of Twitter and geographical locations, have differing attitudes toward IoT.

Methodology and Research Design

Dataset

A search query for collecting Tweet data involves a set of search keywords. Twitter uses the symbol "#" to lead a topic for discussion. This composition mode generates labels called hashtag. Herein, we use '#IoT' as the search query to collect data. As Twitter only allows users to post maximum140 characters, based on the empirical, the Tweets including over four hashtags may lack enough message contents, and the discussions may deviate from the core theme. Therefore, in this research, we analyse Tweets with four or fewer hashtags. We continuously collected data from 18th September to 19th September in 2017; a total number of 59822 Tweets was recorded. We removed retweeted status, as the self-produced Tweet can better reflect individual attitude. The final dataset includes 19298 tweets. We used different screening rules to select sub-samples for analysing different variables; Table 1 summarizes the screening rules and the sub-sample size of each variable.

Table 1. Screening Rules for Variables and Corresponding Sample Size

Variables	Screening Rules	Sample Size
Theme	Remove retweeted status from the collected data.	19298
Usage frequency	Select 805 user ids and crawl one-week history data for every user. The upper limit for every user is 100 tweets.	32260
Profile location	Select 3000 tweets tagging locations in their user information.	3000
Geographical location	Select all tweets which provide valid coordinates.	106

Computer-Assisted Content Analysis

Content analysis is a method of analysing various types of information, including written, verbal or visual communication message (Cole 1988). The technique provides inferences through systematic treatment of content analysis data (Krippendorff 2013).

Conventional content analysis usually relies on human coders and pre-defined coding schemes to discover the existence of dominant concepts. The limitations can result in a series of time-consuming and resource-intensive tasks (Indulska and Hovorka 2012). To address the limitations and provide more objective inferences, we employed computer-assisted content analysis approaches: Sentiment Analysis and Latent Semantic Analysis.

Sentiment Analysis

In this study, we applied sentiment analysis to identify the positive and negative attitude of tweets. One of the feasible approaches to make sentiment analysis of Twitter data is mathematical and statistical computation based on term frequency and term co-occurrence (Bonzanini 2016). We can use sentiment orientation (SO) to represent the sentiment score of a sample text. The value of SO can be a positive or negative, which represents the positive or negative attitude respectively.

SO is calculated by the following equation. The fundamental logic is to identify the polarity of the sample text.

$$\mathrm{SO(t)} = \sum_{t' \in v^+} PMI(t, t') - \sum_{t' \in v^-} PMI(t, t')$$

In this equation, V^+ represents the positive terms and V^- represents the negative terms. The lists of positive terms and negative terms are built before analysing tweets.

PMI is the function of Pointwise Mutual Information. It is used to calculate how close a term is with another term. The calculation of PMI is shown below:

$$PMI\ (term1, term2)\ =\ log(P(term1 \cap term2)/P(term1)P(term2)).$$

Where P(term) represents the probability of the term occurrences, and the P(term1∩term2) represents the probability of term1 and term2 occurring together.

In general, attitudes can be divided into positive, negative, and neutral. We thus initially generated three categories in the coding scheme. Table 2 shows the coding scheme for Twitter users 'attitudes. To classify tweets based on the scheme, we apply the algorithm-based classifier and calculate SO for each tweet.

Table 2. Initial Coding Scheme for Twitter User Attitude

Coding Categories	Descriptions	Example Posts
Positive	The Tweet describes a positive attitude toward IoT.	"you guys are on a roll for more than a decade, awesome stuff. excited for new iot technologies."
Negative	The Tweet describes a negative attitude toward IoT.	"why is enterprise trending down? business understanding of IoT benefits - stacey on iot."
Neutral	The Tweet describes an attitude that is neither positive or neutral.	"power management for internet of things (iot) system on a chip (soc) development."

Latent Semantic Analysis

To understand the context of the attitude, we intend to drill down to the underlying data. Latent Semantic Analysis (LSA) is the appropriate content analysis method to deal with this work. It is used to explore relationships within a corpus of text by mathematical and statistical algorithms (Indulska and Hovorka 2012). Compared with traditional natural language processing or artificial intelligence technique, it parses raw text into words, which regarded as unique character strings, and separate the data into meaningful sentences or paragraphs without humanly constructed dictionaries (Landauer and Foltz 1998).

In this study, we use Leximancer to conduct LSA. Leximancer is a text analytics tool that operates without a standard code or retrieve basis and provides extracted information visually based on the arithmetic of LSA. Therefore, it avoids several coding problems, such as bias and distortions of coding system. Additionally, it also ensures the transparency and replicability of content analysis (Crofts and Bisman 2010).

The program introduces the function of concept learning based on "iteratively extending the seed word definition" (Crofts and Bisman 2010) and information of term-occurrence to suggest meaningful clusters defined as thesaurus of terms for each concept.

We can view the relationships of concepts through a concept map generated by the program to understand the topics of the textual data. In the concept map, the final updated concepts are clustered into themes if they appear together often in the same separated sentences. Moreover, the concept will be placed near another co-occurring concept. These themes can be used to interpret the meaning of the clusters.

Results Analysis

Attitudes Toward IoT

Through the classifier based on sentiment analysis, we calculated the semantic orientation of tweets. The results are displayed in Figure 1. Most users are neutral. The number of positive information is far more than the amount of negative information.

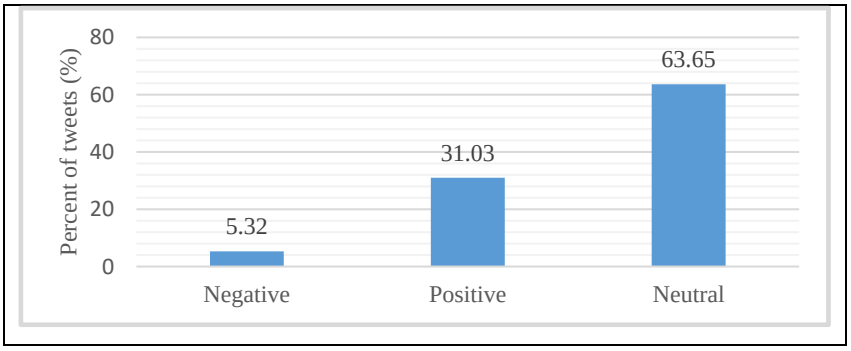

Figure 1. Attitudes Toward IoT in All Tweets

Further, we used the classifier to calculate the score of sentiment orientation for every hashtag related to IoT. Table 3 lists the top three positive hashtags and top three negative hashtags. We found that the top three positive hashtags are associated with information technologies. In contrast, all the top three negative hashtags are associated with privacy and security issues. Table 3 together with Figure 1 suggest that 31.03% Twitter users express positive attitudes; most of their attitudes are related to information technologies. However, most users who post negative attitudes cite the issue of privacy and security as their top concern.

Table 3. Top 3 Positive Terms and Top 3 Negative Terms

Positive Hashtags	Score (SO)	Negative Hashtags	Score (SO)
#fintech	57.08	#vulnerabilities	-44.96
#technews	55.79	#security	-43.94
#armtechcon	48.40	#arbitrary	-38.06

Attitudes Toward IoT by Concept

In this section, the outputs of the concepts are generated based on Leximancer. They explain the topics of IoT in all the collected tweets.

Figure 2 displays the relationships of concepts, the circles labelled by themes represent the size of constructed clusters. The program uses the concept which contains the most neighbours as the theme of this cluster. The most frequently occurring themes are ranked under the concept map. “iot” is the most important theme in the tweets. We also intend to analyse the message content of tweets related to IoT. Thus, we analysed the theme through viewing the concepts in theme “iot” (see Figure 3).

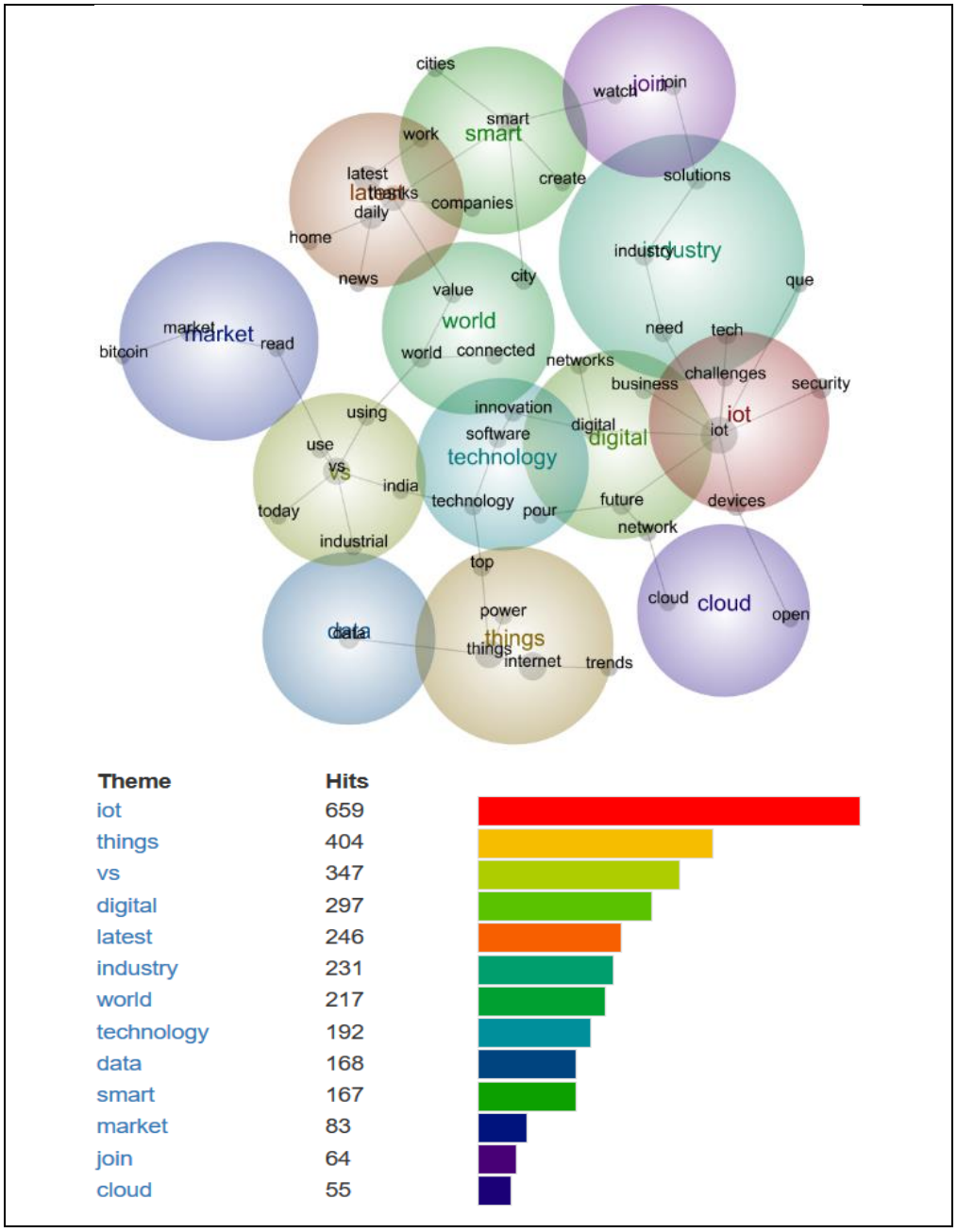

Figure 2. Concept Map for All Collected Tweets and Related Theme Strength

Related Name-Like		Count	Likelihood
Related Word-Like	**Count**	**Likelihood**	
networks	44	96%	
software	49	71%	
devices	70	64%	
security	95	62%	
digital	72	62%	

Figure 3. Concepts of Theme "iot"

Figure 3 shows the top 5 concepts related to "iot". Figure 3 suggests that when users discuss IoT they also talk about concepts related to "network", "software", "devices", "security", and "digital". As the

top three concepts interpret the development of IoT, we can infer that the discussion of users is strongly focused on the development of IoT. Moreover, "security" appears the most times with "iot" in the data set. Thus, the security of IoT is becoming the most concerned issue of users.

Attitudes Toward IoT by Usage Frequency

We defined ten intervals from 0 to 99 and an extra category to store users who posted more than 100 messages. After allocating all sample data into categories, we produced the results shown in Figure 4.

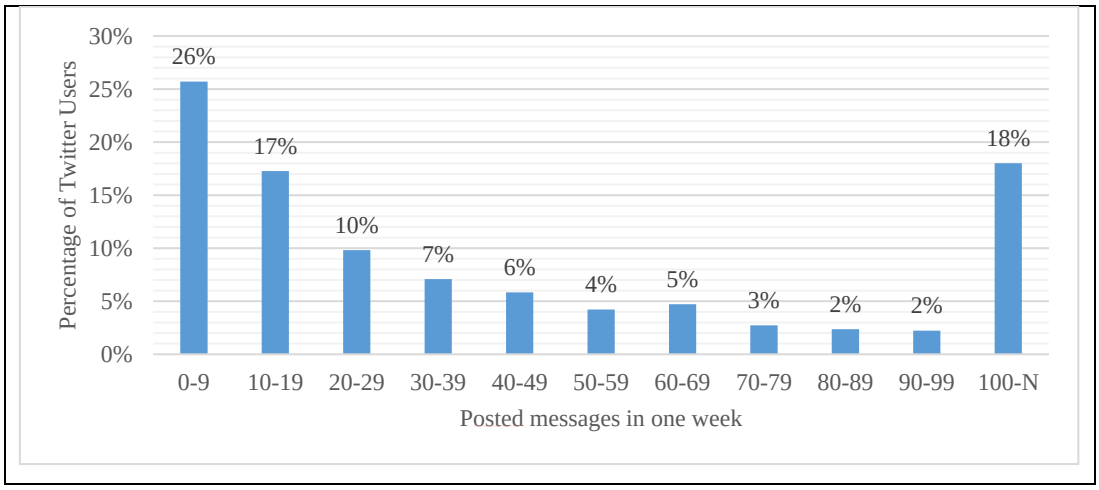

Figure 4. Usage Frequency of Users in One Week

With the increased number of tweets, the number of users tends to decrease. Most users post less than ten messages per week. The number of users falls by one-third when the usage frequency turns into the next interval (10-19). It presents an apparent decrease when the posted messages are over 50.

Moreover, 18% of users post more than 100 messages. We collected all the history tweets of the users in the category of over 100 messages and found that several users post more than 1000 messages per week; those users are usually business account owners and often use Twitter for marketing purposes.

Nearly a quarter of users post less than ten messages per week. These users post 1 to 2 messages in average every day. It means that this kind of users lacks inter-personal interactions on Twitter, such as retweeting and communication with others.

Further, we analysed the attitudes towards IoT by different usage frequency band. We randomly selected 150 tweet users who post less than 100 historical tweets per week as a sub-sample and categorised them in the previous intervals. We calculated that 92.7% users post less than 50 messages per week, and that 42.7% users post less than 10 messages per week. We counted the percentage of positive/negative/neutral attitudes in different usage frequency intervals, as shown in Figure 5.

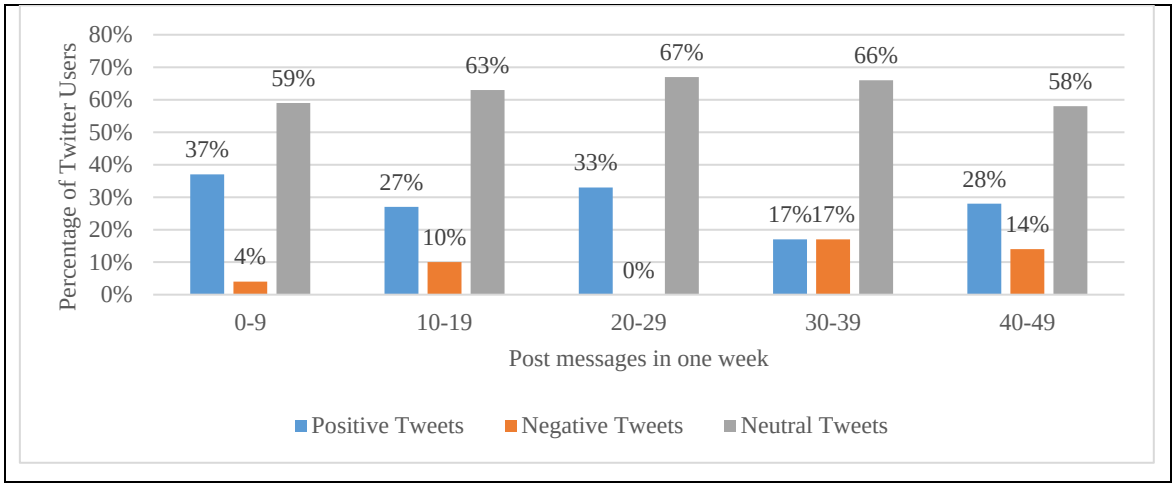

Figure 5. Attitudes Toward IoT by Usage Frequency

Figure 5 does not show a strong relationship between usage frequency and users' attitudes toward IoT. The positive attitudes appear in all the five intervals. Thus, usage frequency of IT platforms might not influence users' attitudes toward IoT.

According to the usage frequency of these users, we analysed the concepts in the high usage frequency users (post greater than or equal to 10 tweets per week) and low usage frequency users (post less than 10 tweets per week). The concept map of each situation is shown in Figure 6.

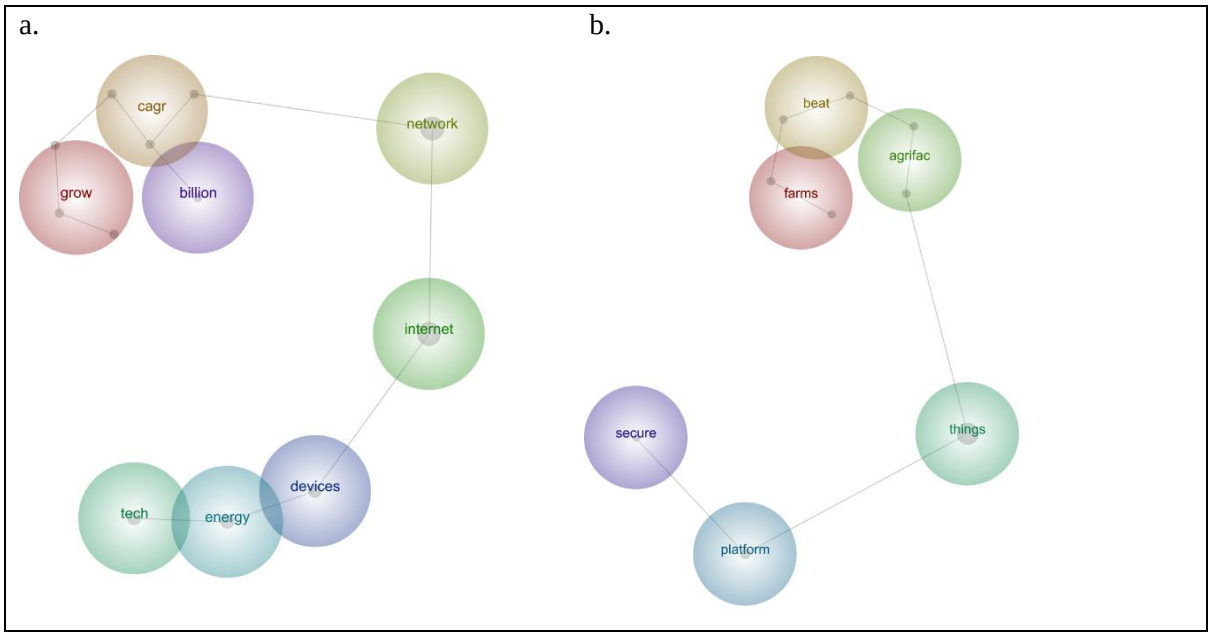

Figure 6. Concept Map for the Data Set of Low Usage Frequency (a) and High Usage Frequency (b)

Figure 6 (a) indicates that the tweets with low usage frequency focus on finance and development, but the tweets with high usage frequency (see Figure 6b) pay more attention to the issue of security and application of IoT. It suggests that the topics of IoT change with the increase of usage frequency. Even though the security of IoT is the most concerned topic, the topic tends to be only related to users who frequently use Twitter.

Attitudes Toward IoT by Geographical Location

According to the previous findings, we already understand that most negative attitudes toward IoT are associated with the issues of privacy and security. However, the development of security strategies for

network users in different countries with different levels of human-rights protection has regarded to be complicated (Callanan et al. 2015). The general findings can not represent the individuals in specific countries. The previous research claimed that network users from developed and wealthy markets are more aware of privacy concerns than the users from the less developed and less wealthy markets (Callanan et al. 2015). Hence, we can hypothesize that the geographical location also can be a significant factor for affecting Twitter users' attitudes toward IoT.

We extracted the locations of users, which provided by themselves. Then, we calculated term frequency of these locations and listed the top six countries. These countries cover most of the sampled users, as shown in Table 4.

Table 4. The Top 6 Countries Cover the Distribution of Profile Location

Country	Number of Tweets	Percent (%)
USA	715	23.8
UK	284	9.5
India	246	8.2
France	189	6.3
Italy	161	5.4
Germany	123	4.1

In Table 4, the USA has the most number of users showing attitude about IoT. It has more than twofold tweets than the second country, the UK. The remaining nations occupy less than 10% samples.

The distribution is relatively concentrated. Attitudes of the public mostly occur in the regions advanced in information technology. Therefore, the users in these areas would like to pay more attention to the development of IoT.

We then analysed attitudes toward IoT by different nations. We selected 150 tweets as a sub-sample and identified the attitudes within each nation (see Figure 7).

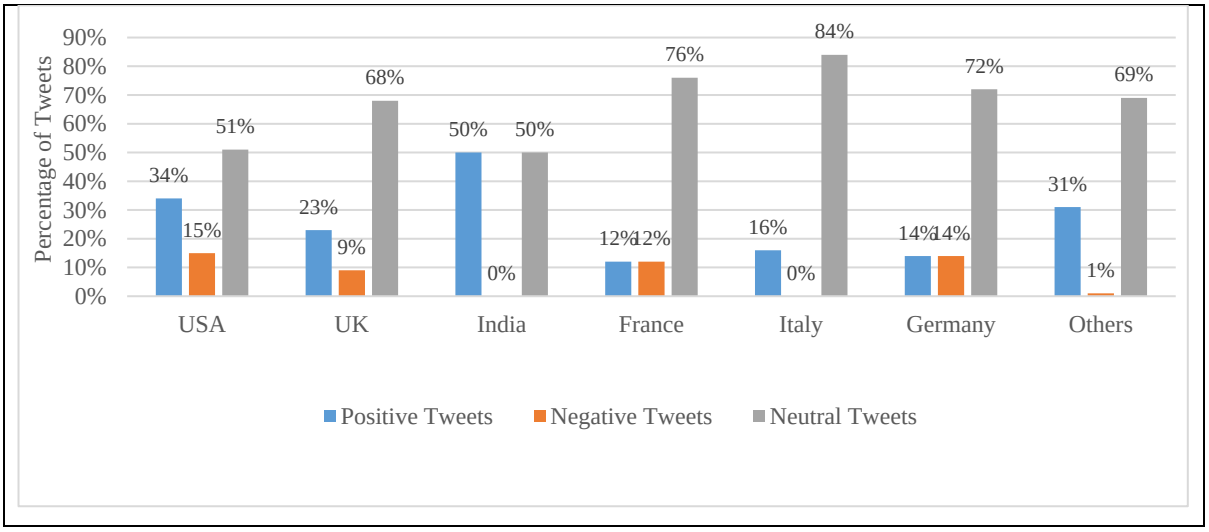

Figure 7. Attitudes Toward IoT by Geographical Location

Figure 7 suggests that most negative attitudes toward IoT come from the USA, UK, France, and Germany. Twitter users in India have most positive attitudes toward IoT and no negative attitudes. In addition to the top six, other nations mostly have positive attitudes towards IoT. To sum up, Twitter users from different countries tend to have different attitudes toward IoT. Twitter users in developed countries are more likely to manifest their worries toward IoT than the users in developing countries.

We further extracted the geographical coordinates from the Georeferenced sample tweets. The geographical locations are captured by built-in GPS receivers in mobile terminals when users post the

message and share their current position. As most tweets come from the USA, the geographical distribution of those tweets is shown in Figure 8.

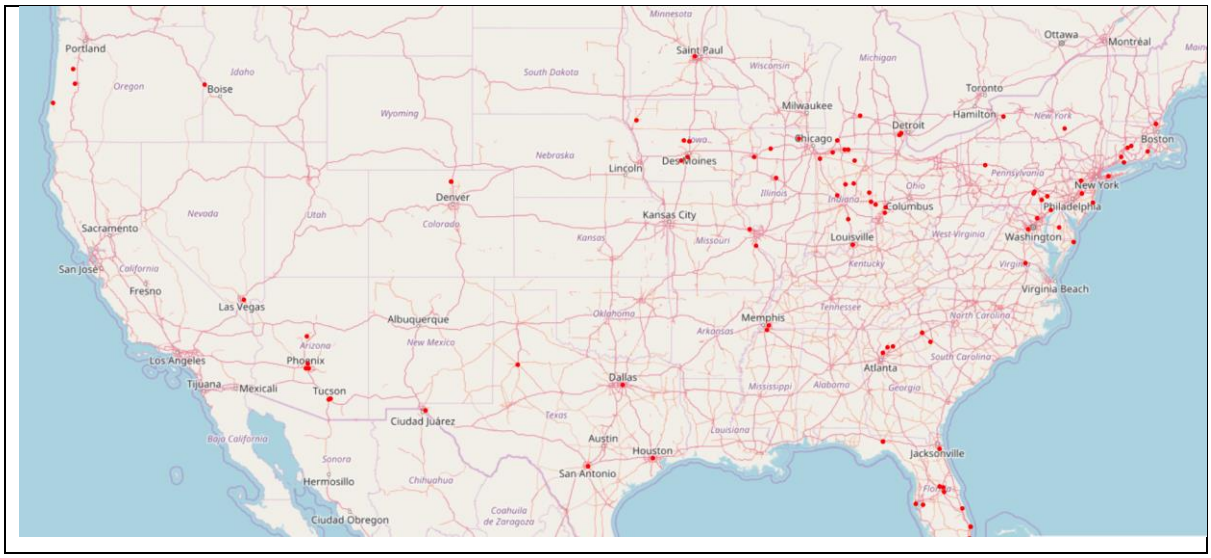

Figure 8. Interactive Map of Geographical Location in the USA

We used red dots to represent tweets. Coastal areas have a higher density of tweets than other regions. Most of the tweets concentrate on the eastern region. A few tweets come from the western region. The coastal areas and the eastern side of the USA are the most developed areas in the economy. As most relevant behaviours occur in these regions, the attitude toward IoT may be associated with the economy and population density.

Concluding Remarks

In this paper, we identified Twitter users' attitudes toward IoT. Three variables are analysed, including concept, usage frequency, and geographical location. To analyse attitudes of Twitter users, we applied content analysis. We used sentiment analysis to identify bipolar attitudes toward IoT and found the favourite field and the concerned issue related to IoT. Most of Twitter users present favourable attitudes toward IoT, but there exists a universal phenomenon of ambiguous attitudes. Therefore, to understand these attitudes, we discovered more categories of topics by LSA. The findings reveal that Twitter users often express attitudes toward IoT in development fields. Combining the results of two methods, our analysis shows that most Twitter users are interested in the technology of IoT, but the issue of security and privacy is a concern. Users who have frequent interaction with IT platforms are most likely to discuss issues of security toward IoT.

The results suggest that a certain number of user lack communication with other users and the concerned fields shifted with the change of usage frequency. Initiating relevant discussion in different user groups is a feasible approach to increase users' interaction, boost the degree of activity, and catch more attention.

On the other hand, the backgrounds of Twitter users are analysed. The analysis suggests that the less usage frequency of the users is, the more tweets related to IoT is. However, usage frequency of Twitter may not have significant influence on users' attitudes toward IoT. We also analysed the distribution of tweets in different countries. We inferred that most tweets about IoT are generated in the coastal areas and the eastern side of the USA. Moreover, as the locations of Twitter users are different, the attitudes toward IoT may change. Most active users come from developed countries. Future research may address attitudes toward IoT in developing countries. The insights gained may help development of IoT and management of online communities.

The limitations of the study consist of two aspects: First, we only considered the public's attitudes on Twitter. The change of the IT platform use is also important, because the behaviours in different platforms may be different. Second, we analysed attitudes based on different intervals of usage

frequency, but fewer user IDs are taken into account. We intend to address limitations in the further research.

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