University Transportation Research Center - Region 2

Final Report

Integrating Real-time GIS and Social Media for Qualitative Transportation Data Collection

Performing Organization: City University of New York (CUNY)

December 2016

Sponsors:
University Transportation Research Center - Region 2
Federal Highway Administration/USDOT

University Transportation Research Center - Region 2

The Region 2 University Transportation Research Center (UTRC) is one of ten original University Transportation Centers established in 1987 by the U.S. Congress. These Centers were established with the recognition that transportation plays a key role in the nation's economy and the quality of life of its citizens. University faculty members provide a critical link in resolving our national and regional transportation problems while training the professionals who address our transportation systems and their customers on a daily basis.

The UTRC was established in order to support research, education and the transfer of technology in the field of transportation. The theme of the Center is "Planning and Managing Regional Transportation Systems in a Changing World." Presently, under the direction of Dr. Camille Kamga, the UTRC represents USDOT Region II, including New York, New Jersey, Puerto Rico and the U.S. Virgin Islands. Functioning as a consortium of twelve major Universities throughout the region, UTRC is located at the CUNY Institute for Transportation Systems at The City College of New York, the lead institution of the consortium. The Center, through its consortium, an Agency-Industry Council and its Director and Staff, supports research, education, and technology transfer under its theme. UTRC's three main goals are:

Research

The research program objectives are (1) to develop a theme based transportation research program that is responsive to the needs of regional transportation organizations and stakeholders, and (2) to conduct that program in cooperation with the partners. The program includes both studies that are identified with research partners of projects targeted to the theme, and targeted, short-term projects. The program develops competitive proposals, which are evaluated to insure the mostresponsive UTRC team conducts the work. The research program is responsive to the UTRC theme: "Planning and Managing Regional Transportation Systems in a Changing World." The complex transportation system of transit and infrastructure, and the rapidly changing environment impacts the nation's largest city and metropolitan area. The New York/New Jersey Metropolitan has over 19 million people, 600,000 businesses and 9 million workers. The Region's intermodal and multimodal systems must serve all customers and stakeholders within the region and globally.Under the current grant, the new research projects and the ongoing research projects concentrate the program efforts on the categories of Transportation Systems Performance and Information Infrastructure to provide needed services to the New Jersey Department of Transportation, New York City Department of Transportation, New York Metropolitan Transportation Council , New York State Department of Transportation, and the New York State Energy and Research Development Authorityand others, all while enhancing the center's theme.

Education and Workforce Development

The modern professional must combine the technical skills of engineering and planning with knowledge of economics, environmental science, management, finance, and law as well as negotiation skills, psychology and sociology. And, she/he must be computer literate, wired to the web, and knowledgeable about advances in information technology. UTRC's education and training efforts provide a multidisciplinary program of course work and experiential learning to train students and provide advanced training or retraining of practitioners to plan and manage regional transportation systems. UTRC must meet the need to educate the undergraduate and graduate student with a foundation of transportation fundamentals that allows for solving complex problems in a world much more dynamic than even a decade ago. Simultaneously, the demand for continuing education is growing – either because of professional license requirements or because the workplace demands it – and provides the opportunity to combine State of Practice education with tailored ways of delivering content.

Technology Transfer

UTRC's Technology Transfer Program goes beyond what might be considered "traditional" technology transfer activities. Its main objectives are (1) to increase the awareness and level of information concerning transportation issues facing Region 2; (2) to improve the knowledge base and approach to problem solving of the region's transportation workforce, from those operating the systems to those at the most senior level of managing the system; and by doing so, to improve the overall professional capability of the transportation workforce; (3) to stimulate discussion and debate concerning the integration of new technologies into our culture, our work and our transportation systems; (4) to provide the more traditional but extremely important job of disseminating research and project reports, studies, analysis and use of tools to the education, research and practicing community both nationally and internationally; and (5) to provide unbiased information and testimony to decision-makers concerning regional transportation issues consistent with the UTRC theme.

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New technologies such as global positioning system, smartphone, and social media are changing the way we move around. Traditional transportation research has overwhelmingly emphasized the collection of quantitative data for modeling, without much collection of qualitative data to understand the processes of why and how individuals make their travel choices. We developed a prototype in this project to use real-time GIS and social media (Twitter) to collect, analyze, and display qualitative travel information from individuals. There are two goals in this research project. One is to collect tweets from individuals to speculate the trip purposes of their travels. The prototype developed in this project collects tweets from volunteers and calculates the probabilities of their trip purposes from what they tweet about in Twitter. Another goal of this research is to display tweets on the web through real-time GIS. This would be very useful during emergency evacuations in extreme events such as 9/11 and Hurricane Sandy. The project is directly relevant to UTRC's research focus area 4 "system modernization through implementation of advanced and information technologies" and research focus area 8 "securing transportation systems and improving planning for and response to extreme events."</td></tr>
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New technologies such as global positioning system, smartphone, and social media are changing the way we move around. Traditional transportation research has overwhelmingly emphasized the collection of quantitative data for modeling, without much collection of qualitative data to understand the processes of why and how individuals make their travel choices. We developed a prototype in this project to use real-time GIS and social media (Twitter) to collect, analyze, and display qualitative travel information from individuals.

There are two goals in this research project. One is to collect tweets from individuals to speculate the trip purposes of their travels. In transportation planning, the activity-based model system is considered as the next-generation demand-forecasting model and requires the input of trip modes and purposes of individuals. GPS-based travel surveys can avoid many problems in traditional paper and phone surveys and are becoming increasingly popular in major cities worldwide. We have previously developed a computing system consisting of a smartphone app that transmits GPS data to an Amazon cloud server where GIS algorithms detect travel modes of individuals. However, because of the urban canyon effects and mixed land use typical in high-density cities such as New York City (NYC), speculating trip purposes has proved to be very challenging without qualitative information from survey participants. The prototype developed in this project collects tweets from volunteers and calculates the probabilities of their trip purposes from what they tweet about in Twitter.

Another goal of this research is to display tweets on the web through real-time GIS. People can find out the conditions of transportation infrastructure (such as train delays, subway station closure) on the real-time web GIS when there are tweets about them. This would be very useful during emergency evacuations in extreme events such as 9/11 and Hurricane Sandy because people can get information from the tweets about what transportation facilities are damaged and closed even before they are reported in TV.

2. Research approach, Existing Resources, and Study Area

Our research approach is presented in Figure 1 in a nutshell. There are three main components in Figure 1. The first main component is the smartphone, from which a tracking app sends in location information (from GPS, WiFi, or cell towers) and the Twitter app sends in tweets about travel mode, trip purpose, and transportation facilities. The second main component is the cloud computing where GIS algorithms identify travel modes and trip purposes from location information and tweets as well as providing data services on the conditions of transportation facilities. The third main component is the Web GIS that displays real-time tweets on transportation facilities and trip information.

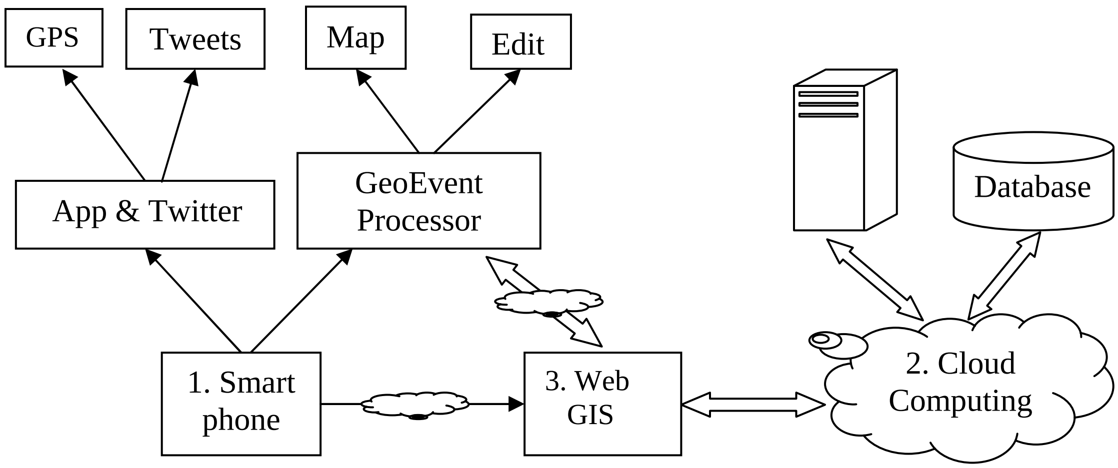

Figure 1. Three main components of the project

Over the past few years, we have also built a multimodal transportation network for NYC, incorporating all streets and highways as well as their directions, bus routes and stops, subway lines and entrances, commuter rails and stations, ferry lines and landings. Using this multimodal transportation network, we have developed a GIS algorithm to detection travel modes from GPS traces in NYC with an 82.6% success rate (Gong et al., 2012) and a GIS model to speculate trip purposes (Chen et al., 2010). They can be modified to combine qualitative information from tweets to improve the success rates of identifying travel modes and trip purposes in a cloud server. We also developed a Web GIS for validation of post-processed results from GPS data. It can be adapted for use in a smartphone platform and for displaying real-time conditions of transportation facilities. Most recently, we modified an existing tracking app to send location (GPS) information from smartphones to our cloud server. These location information and tweets from smartphones will be combined for use in our cloud server.

We choose New York City as the study area for this project because the complexities of its transportation networks, land use patterns, and urban landscapes. The complex urban environment in NYC posts many challenges to post-processing of GPS data for travel mode detection and trip purpose identification. The first challenge is that there is an extensive subway network and most of the commuter rail tracks (especially in Manhattan) are also underground. Smartphones cannot receive satellite signals underground and therefore cannot log location unless there is WiFi or cell signals from the wireless carrier (with very limited availability and inaccurate location information). The second challenge is urban canyon effect created by dense and tall buildings, causing GPS in a smartphone to derive inaccurate location. The third challenge is cold/warm start problems. In addition to the failure of cold starting in Manhattan, the average warm start time emerging from underground is 39 seconds and may go up to 106 seconds according to our field testing in NYC. During warm starts, survey respondents continue walking away from the subway station, causing many subway trips misclassified in our mode detection study (Gong et al., 2012). The fourth challenge is the high-density mixed land use in NYC, making it impractical to identify trip purpose by associating a cluster of GPS points with land use data. Getting qualitative information (tweets) from the users will no doubt help in the identifications of travel modes and trip purposes.

In addition to the technical difficulties in obtaining accurate location information, New York City is a global city and a financial center of the world. It is prone to terrorist attacks such as 9/11 and terrorist plots such as the ones to blow up the Holland Tunnel in 2006 and JFK Airport in 2007 (Gong and Keenan, 2012). New York is also a megacity in which natural disasters such as Hurricane Sandy could affect millions of people. While it takes hours for conditions of transportation facilities to be reported in the news, real-time display of their conditions from tweets on a website will be useful in guiding emergency evacuations in extreme events such as human-induced and natural disasters. Combining qualitative information from social media, such as tweets from Twitter in smartphones, has advantages over using just the quantitative location information in meeting the challenges in mega city such as New York. We expect that the approach developed from this project will most likely be applicable to less complex and smaller cities when it is used with the local transportation and land use data in these areas.

3. System Overview of the Prototype

Figure 2 provides a system overview of the prototype that we developed based on existing resources to achieve the two goals of the research. The top workflow in the figure represents our previous work on trip identification. The bottom workflow achieves our first goal. It classifies tweets and integrates the trip purpose results with previous trip identification work in TripVisualizer on the web. The middle workflow achieves our first goal and displays tweets on the web through real-time GIS.

Firstly, to help identifying trip purposes of survey participants, participants will download our app from our web site and register using the same user names as their Twitter accounts. Their posts on Twitter are classified into probabilities of nine trip purposes and are combined with trip results from the existing mode detection algorithm. In this case, it is not required that their Tweets are geo-tagged with latitude/longitude coordinates, or contain any location references, as their location information is already available from the GPS tracking function on the app. Their location at the time of a specific tweet can be identified using the tweet's time stamp. This way, we circumvent the fact that only about 1% of all Twitter users turn on geotagging for the tweets (Compton et al., 2014; Gomba, 2012).

Secondly, the same function can be used on Twitter's streaming APIs (https://dev.twitter.com/streaming/public) to monitor the social media platform for any tweets that contain a certain keyword. In principle, this works for any keyword, but in our use case, we are interested in keywords such as *MTA*, *subway*, *bus*, *commute*, *delay*, *station*, etc. This approach provides access to a wider range of tweets from a broader user base, so that it can be useful in monitoring parameters such as the overall system state or customer satisfaction. However, in contrast to the first use case, the tweets collected this way have to be geo-tagged with latitude/longitude coordinates in order to be useful for spatial analysis. While there are approaches to georeference tweets that are not explicitly geo-tagged based on content (e.g., Laylavi et al., 2016), such as mentioned place names, we limit our work to geo-tagged tweets here.

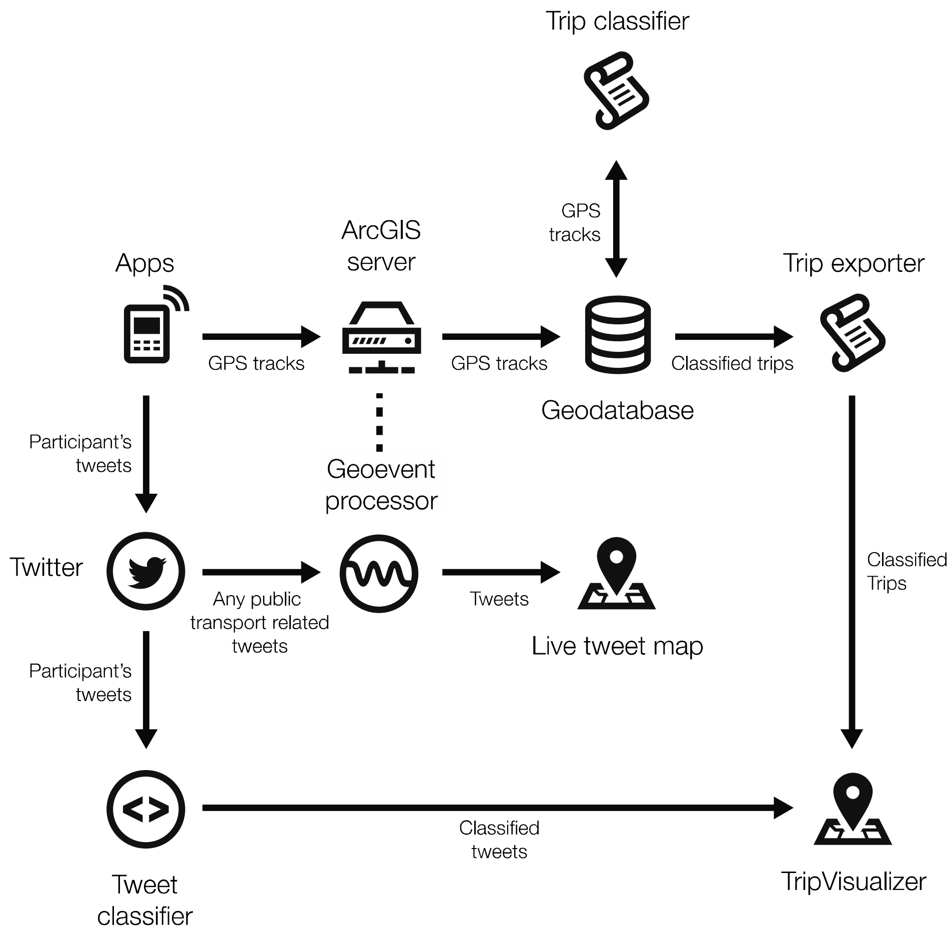

Figure 2. System overview of the prototype

4. Social Media Monitoring and Automatic Classification

We developed a web service that would classify a small string of text (a tweet, restricted to 140 characters by Twitter) into nine predefined classification categories for trip purposes, namely "work or school at regular location", "work or school activities at other places", "shop", "drop off or pick up someone", "eat meal out at a restaurant or diner", "recreation/entertainment", "social/visit friends or relatives", "other family or personal business (health care, religious activities, etc.)", or "none of the above".

A *Tweet Classification Service* was designed and developed in the Java programming language (JDK 7) running a servlet on Jetty 9. The service employs the *Mallet* package for statistical natural language processing and documentation classification (McCallum 2002). The Mallet document classification application programming interface (API) was used to classify documents (tweets) by a predefined set of categories (listed above). Mallet allows for a number of different classification methods and as of this status report, the *Naïve Bayes* method provides the foundation for this service's classification.

As input, the document classifier requires a training dataset. As a first-step, a sample of 2500 geo-tagged tweets was accessed via the *Twitter API* from a region that covers the five boroughs of New York City. After cleaning (removing nonsensical tweets), the tweet contents were then manually classified into one of the above-mentioned nine categories through workers on Amazon's mturk service. These manually assigned classes are termed *Labels* and form the basis for the probabilistic classification of the future content. Since each tweet is assigned a label, the classifier assigns the tokenized content of the tweets to these labels and then attempts to match unclassified tweets based on this knowledge. A similar approach was taken by Hu *et al.* (2014) in the classification of conference abstracts for reviewer assignment.

Given the training set, a *tweet.classifier* file is generated as InferClass endpoint and used as the foundation on which to classify future tweets. The Java servlet was developed as a container for the tweet classifier. Users can access the servlet via a RESTful endpoint which takes a tweet's content (parameter *t*) as input and outputs probability values for each of the categories in JSON format.

A second endpoint, UserInferClass, was constructed that accepts a *Twitter username* as input, accesses the provided user's timeline, downloads the tweets specified by the *page* and *count* parameters, classifies the content of the tweets and outputs category probability values. In order to access a user's twitter timeline, the *Twitter4j2* Java library was employed. This library allows for simple integration of the twitter service with custom Java applications. It is required that any developer wishing to interact with *Twitter* data via the public-facing API register an application and obtain four authorization tokens/keys. This is aimed to ensure fair play as well as restrict the amount of data that can be accessed. A new *Twitter* account has been developed for this project and an application was generated under the name *tweetclass1*. This account is required to obtain the authentication tokens to be able to access the Twitter API, which both the geoevent processor and the tweet classifier use. The required authentication tokens/keys were embedded in the classification service allowing tweets to be accessed for any user provided his or her timeline is tagged as *Public*.

When the classification service endpoint is accessed (provided a username), the tweets for the given user are downloaded and the content is classified based on the tweet classifier established in the previous section. The resulting probabilistic values for each class are then wrapped in a JSON Object consisting of the tweet timestamp and tweet ID (see Figure 3). The data is then returned to the client along with the original username requested. Since the *Twitter API* restricts the number of tweets to 200 per request (300 requests per 15 mins), an additional parameter was added to the classification service that allows for *page* specification as well as the number (*count*) of tweets per page.

```
{
    "user": "lsava7",
    "tweets": [{
        "727633376891555843": {
            "datetime": "Tue May 03 18:58:10 EDT 2016",
            "text": "Headed to this Japanese bookstore by Bryant Park",
            "classification": {
                "recreation": 0.3200605836121392,
                "shopping": 0.30656232687689045,
                "workschool": 0.130599032532667,
                "dropoff": 0.12454052987967464,
                "otherfam": 0.03835464282731652,
                "eat": 0.011842349657145342,
                "none": 0.008273013363105675,
                "social": 0.00809556036052779,
                "workother": 0.0015195548981552529
            }
        }
    }, {
        "727626863439425536": {
            "datetime": "Tue May 03 18:32:17 EDT 2016",
```

Figure 3: Example of a classification for a tweet, with probabilities for each class calculated by Mallet based on the training dataset.

While the original goal was to have each incoming tweet classified on the fly, restrictions in the design of ESRI's Geoevent Processor concerning its ability to interact with custom web services prevented implementation of this workflow. It was therefore decided to take an asynchronous approach, where the Geoevent Processor is primarily used as an interface to the Twitter Streaming API. It is with some relevant search terms and a region (latitude/longitude boundingbox) they are posted in (see Figure 4). The Geoevent Processor then displays the any incoming tweets on the live tweet map (see Figure 5) through a web socket connection, which means that any information received by the Geoevent Processor is automatically pushed to the web map; there is no reloading of the page or other user interaction required.

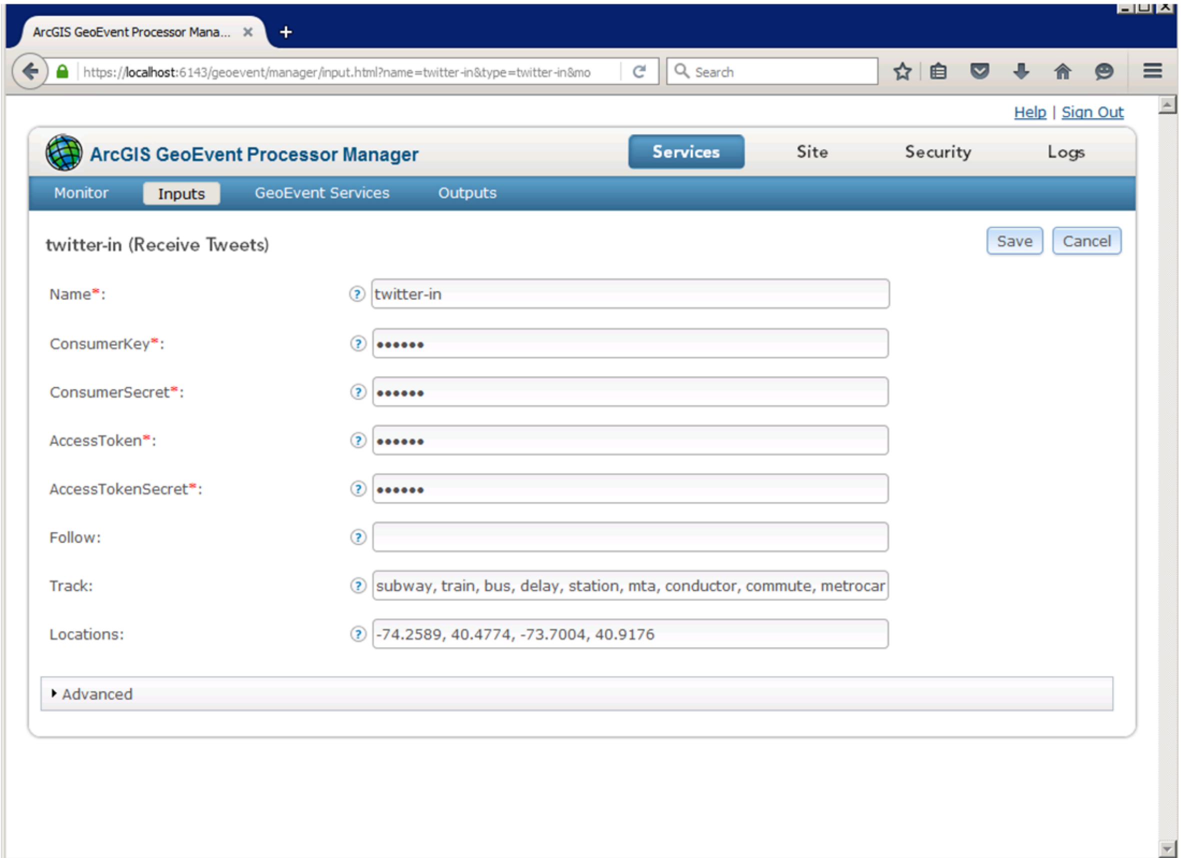

Figure 4: Configuration of GeoEvent Processor Twitter input.

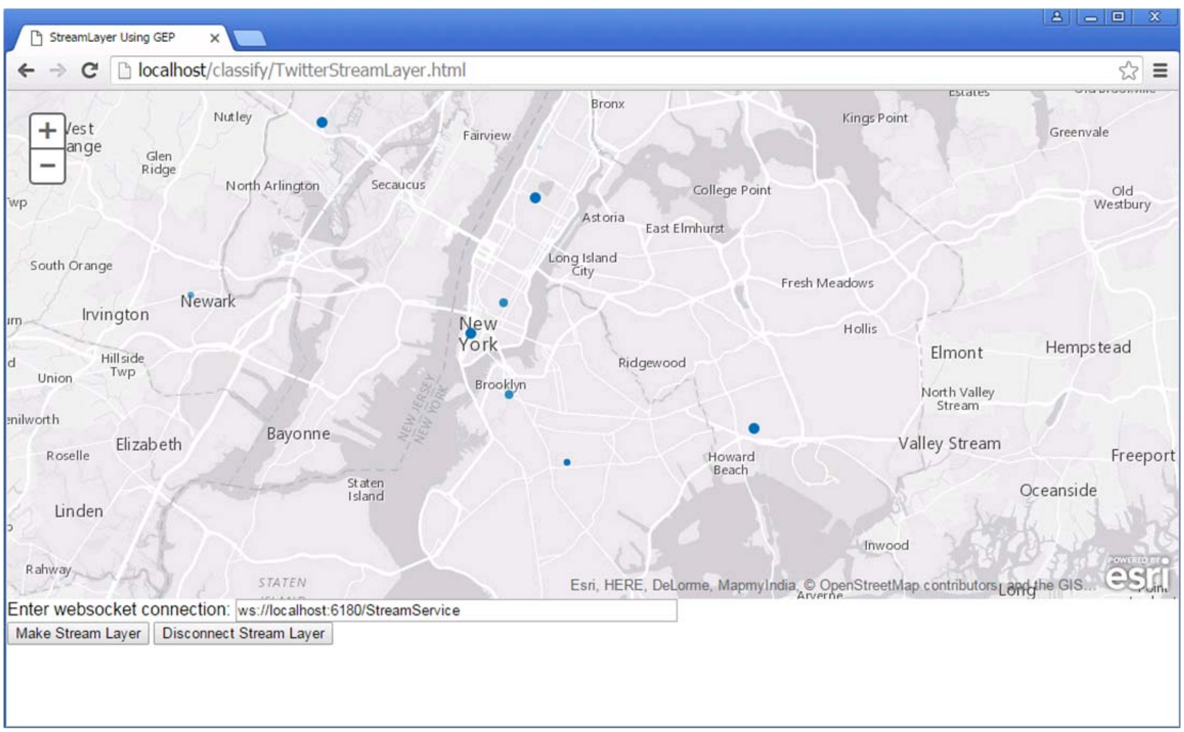

Figure 5: An example of live tweet map.

5. Trip Visualization Web Map

While a web-based visualization and editing application already existed from previous projects, we replaced this flash-based application with a more modern solution based on JavaScript that also works in browsers on smart phones. The new TipViewer was therefore developed in ArcGIS API for JavaScript (https://developers.arcgis.com/javascript/), ESRI's own JavaScript library. It was selected over other popular web mapping frameworks such as Leaflet or OpenLayers because it is optimized for the integration with ArcGIS server and supports data editing on the server out of the box. Unfortunately, this feature could ultimately not be implemented. In order to allow the JavaScript library to access the data in a Geodatabase hosted on ArcGIS Server, the web service functionality for this Geodatabase needs to be activated. Even after several hours on the phone with different levels of consultants at ESRI support, we were not able to activate this function. Therefore, we chose a solution similar in nature to the one we developed for the tweet classifier and the Geoevent Processor (see Section 4). A script was developed that generates exports from the xMode Geodatabase in JSON format once every hour. This asynchronous solution causes a delay of up to an hour between the recording of a trip and its visualization in the trip viewer.

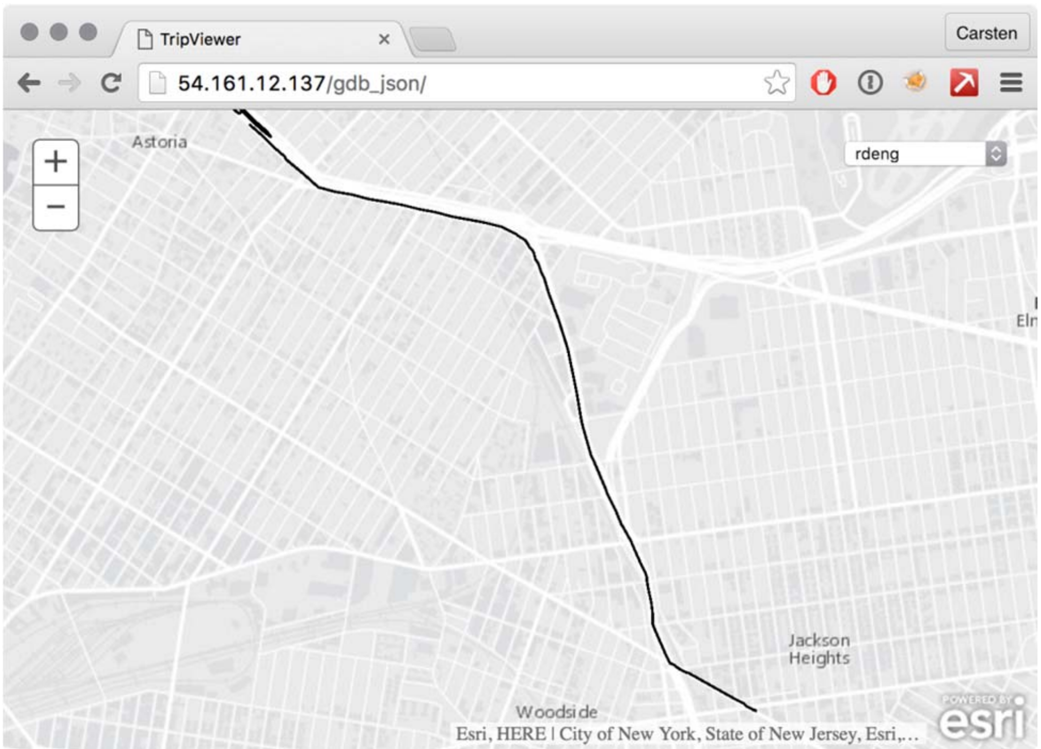

Figure 6: TripViewer in desktop browser.

The current solution is limited in two ways: Since the web services could not be enabled on the Geodatabase, there is currently no editing functionality in the TripViewer. The flow of information goes only in one direction, i.e., from Geodatabase to file export to web map. ESRI's JavaScript library does implement editing functionality, however, so that in future iterations of the project with a fresh server setup, this functionality can be added with a few lines of code.

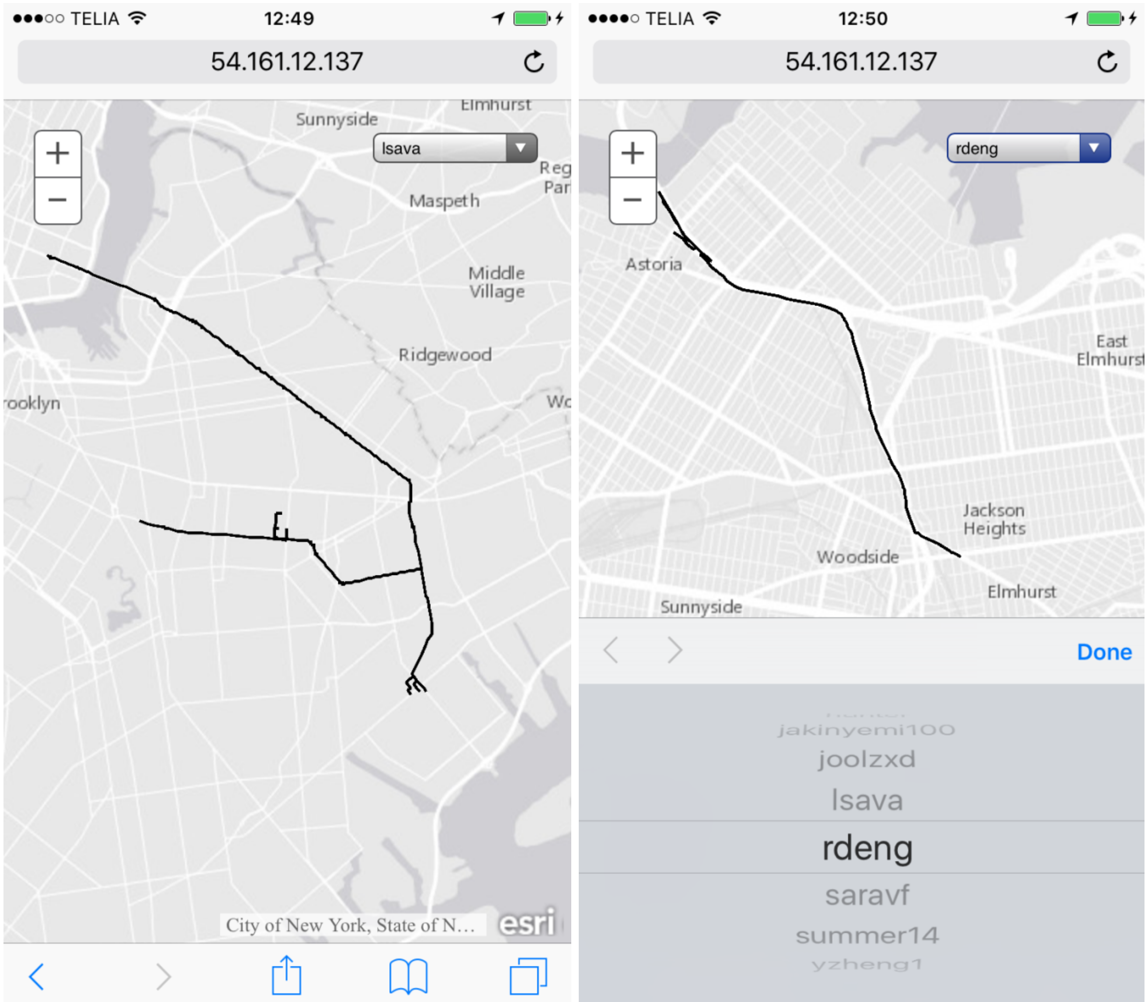

Figure 7: TripViewer in mobile Safari on iOS.

The second limitation is that a map may appear a bit slow for users with many or long trips on mobile devices while it works well on a desktop. Future versions of the viewer should potentially use a thinning algorithm on the trips and only show them in full detail when the user is editing a trip.

6. Conclusions

We developed a prototype in this project to use smartphone app, cloud computing, GIS algorithms, real-time GIS, and social media (Twitter) to collect, analyze, and display qualitative travel information from individuals. The project is directly relevant to UTRC's research focus area 4 "system modernization through implementation of advanced and information technologies." Through the use of GPS, smartphone, and social media, the project has the potential to provide information for transportation modeling (trip purpose in particular) and studying how real-time transportation information affects daily travels. The project is also relevant to research focus area 8 "securing transportation systems and improving planning for and response to extreme events." Through the real-time Web display of tweets, it is helpful to know during emergency evacuations what transportation facilities are damaged or still functioning in extreme events such as 9/11 and Hurricane Sandy.

7. Dissemination of the Project Results

We disseminated the results of this project in a conference presentation and a research brief.

(1). Conference Presentation

Giampieri, M., H. Gong and Kessler, C. Integrating Real-time GIS and Social Media for Qualitative Transportation Data Collection. Presented at Transportation Technology Symposium: Innovative Mobility Solutions, New York, November 20, 2015.

(2). Research Brief

One-page research brief for UTRC2 Newsletter summarizing the methods, findings, and significance of this project.

8. Acknowledgements

Special thanks to Mario Giampieri for his assistance on this project.

References

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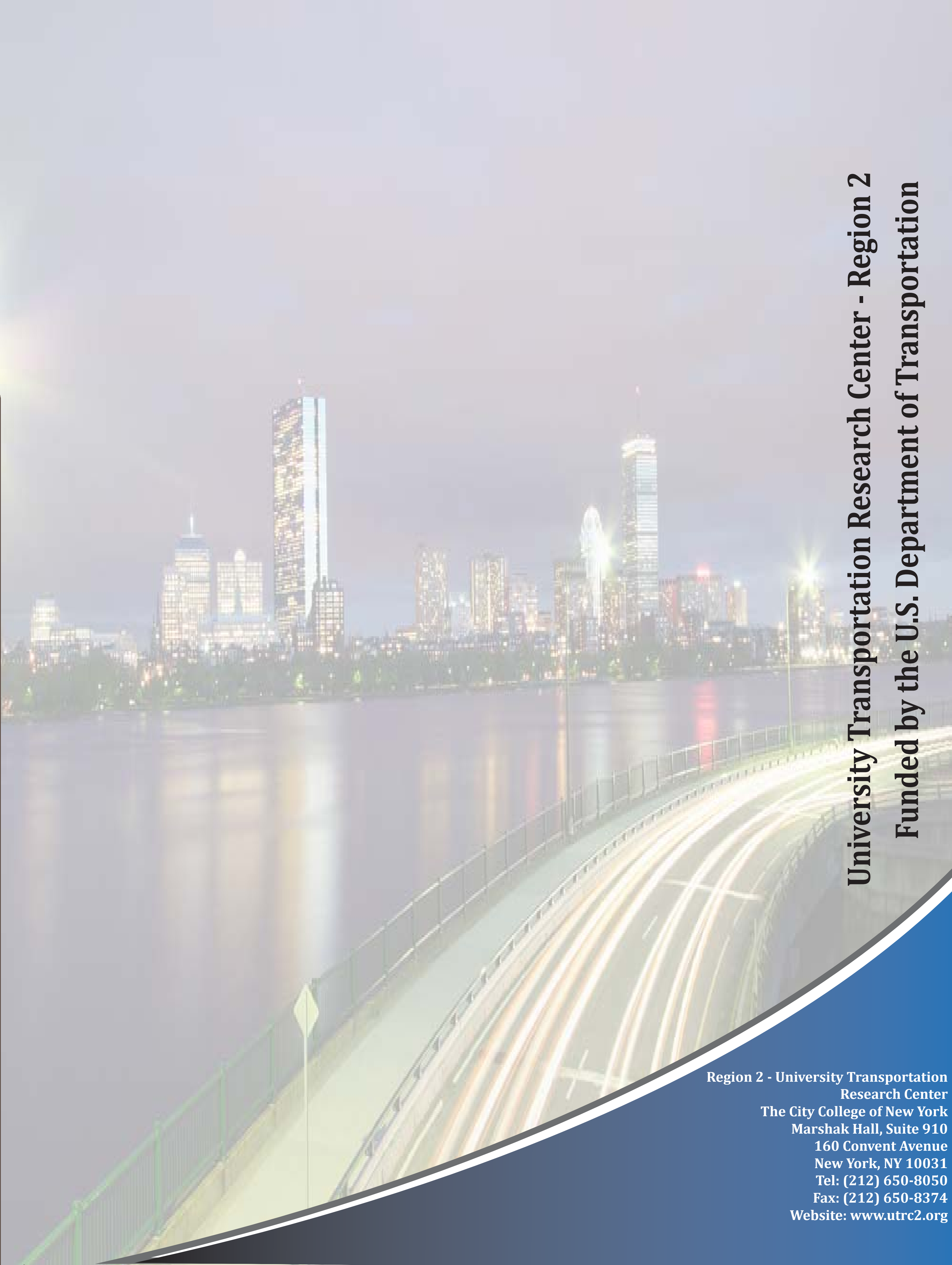

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