

# Appendix

## 1 A detailed description of Bi-LSTM and SLPA model used in SocialDISC

### 1.1 BiLSTM

Bidirectional long short-term memory (BiLSTM) is a type of Recurrent Neural Network (RNN). RNN is influential in processing time-series signals, such as voice and natural language. Different from traditional neural networks, an RNN contains a feedback connection, which is a loop that allows the output of the hidden layers also to be the input of themselves. This feature enables the neural network to use the previously learned information from the earlier part (termed as "memory") and predict the later sections of a time-series signal.

LSTM is a widely used architecture of RNN. It controls the information flow within the neural networks using three types of regulators (usually termed as "gates"): an input gate, an output gate, and a forget gate. These gates can control the weight indicating the degree to which information at a different section of the time series will influence the node parameters. With these regulators, LSTM can overcome the drawback of classic RNNs that cannot correctly utilize the information that is received too early (usually referred to as a vanishing gradient problem). A detailed explanation of RNNs and LSTM can be found at "<https://colah.github.io/posts/2015-08-Understanding-LSTMs/>."

Compared to LSTM, BLSTM or BiLSTM uses two networks, one access past information in a forward direction and another access future in the reverse direction. This structure can improve the performance of understanding, say, the last couple of words in a sentence based on the first couple of words and vice versa.

### 1.2 Speaker-listener Label Propagation Algorithm (SLPA)

SLPA is an iterative clustering algorithm that allows a node to be clustered into multiple overlapping clusters. SLPA is proven to be one of the best algorithms for detecting overlapping communities. It first initializes each node as a cluster. Each node (representing each twitter in this study) has "memory," which consists of all potential labels this node accepted from other nodes. In listener-speaker propagation iterations, the algorithm will select each node to be a "speaker" or a "listener" based on its memory: a listener node accepts the label that is the most popular among its neighbors (identified based on the content similarity of tweets) and accumulates such labels in the memory. More importantly, the more a node receives a certain label, the more likely this node will spread the label to other nodes. After iterations, the algorithm will group connected nodes that share the same label with the weight over a threshold in their memories to a community.

## 2 Societal impact analysis results for the categories not included in the paper

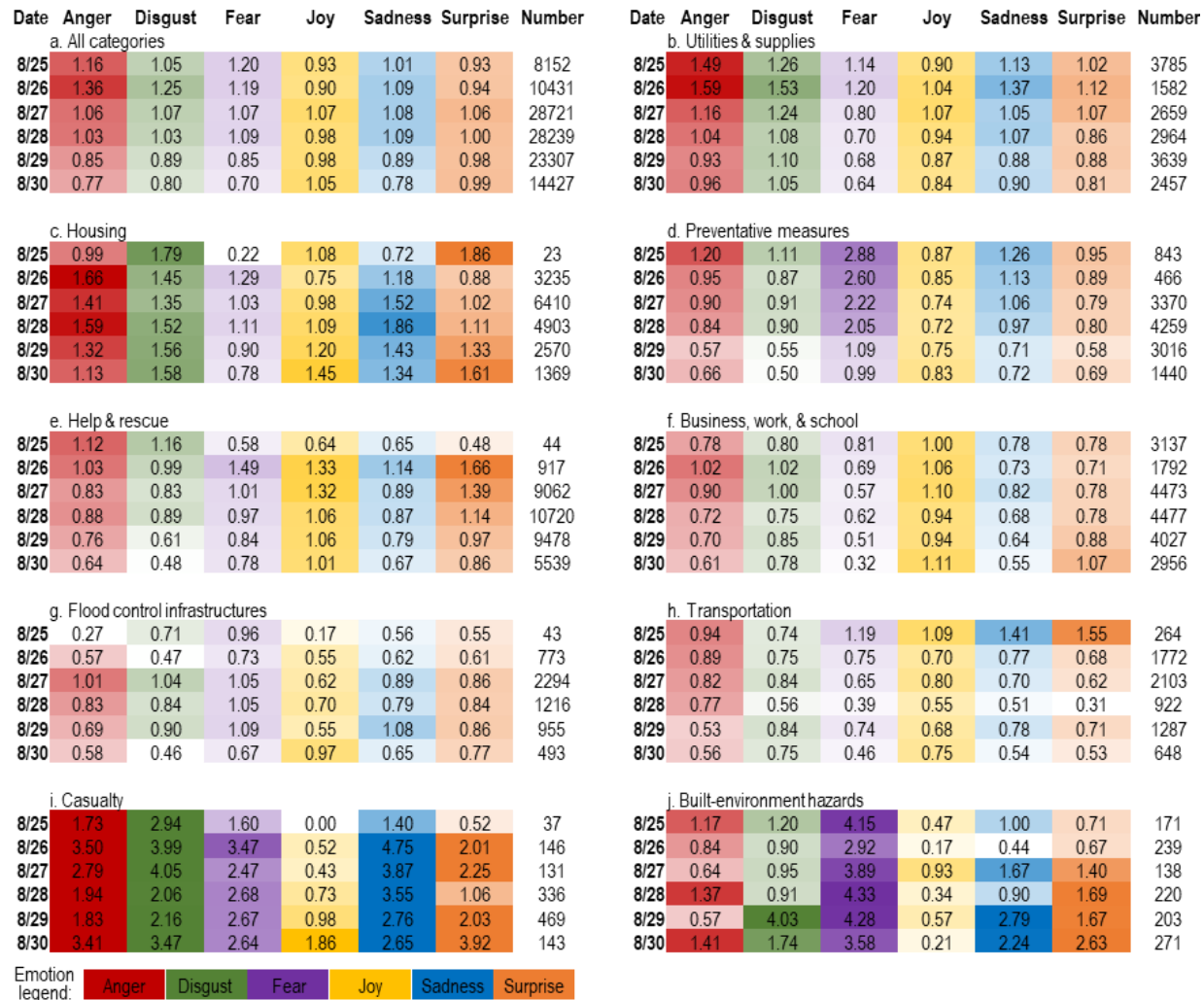


Figure 5. Overview of the societal impact analysis result of Hurricane Harvey

### 2.1 Help and rescue

For the entire period of Aug 25–30, help and rescue tweets were the most numerous among all the categories in our analysis (Figure 5e). Tweets under this category showed less negative emotion compared with their counterparts in other categories, attesting to the positive attitude and strong spirit of the Houstonians when facing Harvey's impacts. Looking at the tweets in this category posted on each day, we can see that only 44 tweets posted on August 25 fell into this category. During August 26–29, the number of tweets increased dramatically (917 tweets on August 26 and more than 9000 on Aug 27, 28, and 29), which shows that the Houstonians actively participated in using social media for seeking and providing aids. In these days, the tweet contents in this category remain constant in general. Important subevents/topics are as follows: "national guard rescued flooded victims;" "residents sought/provided rescues using boats;" "people sought the opportunity to volunteer;" "people donated money and goods to individuals and organizations (e.g., Red Cross);" and "general discussions about people seeking/providing help between neighbors, friends, and family members." On August 30, the number of tweets on "rescue

activities" reduced, and the tweets about "donation and volunteering" increased, indicating the beginning of the relief and recovery.

## 2.2 Business, work, and school

For tweets in the category of *Business, work, and school* (Figure 5f), discussion about the open/closed status of businesses, workplaces, and schools occupied a large (about 15%–40%). Overall, on August 25–28, the tweet subevent of "announcing office or business closed" was the largest one. The number of tweets on this topic reduced between August 29–30 as the topic of "business/office open" grew. August 25–26, people complained about the fact that "they had to work despite the hurricane" and were "stuck at work." Also, people expressed their concern about the "oil and gas business" and "the upcoming school semester might be influenced by the hurricane." August 27–28, "the schools would be canceled for the first week of the semester" emerged as a major topic. August 29–30, the topic of "office/business opening today/tomorrow" was dominating, indicating the beginning of the recovery stage of the hurricane. Interestingly, people strongly expressed their joy in "being able to go back to work or school" (joy: 2.14), which is a contrast to those who complained about having to work despite the hurricane during August 25–26. Tweets in this category showed us that people being able to return to work is a symbol for the relief of things returning to a normal routine.

## 2.3 Flood-control infrastructure

On August 25, only a small number of tweets fall within the flood-control infrastructure category, which discussed the water level of bayous and the tornado near the Buffalo Bayou (Figure 5g). On August 26, people were sharing information about "bayou water levels" and "reporting bayou overflows." The information regarding "bayou overflows" and "reservoirs expected to reach record levels" caused a high level of anger (2.97) and disgust (3.38) evident from the number of swear words used.

On August 27–28, the number of tweets about "water level of bayous" and "reservoirs" increased up to about 300% compared to August 26. Such a significant increase was due to the threatening situations of the reservoirs and bayous and the decision for releasing the water from two major reservoirs: Addicks and Barker. This increase corresponded with the peak of sadness and disgust in the housing category because the water release from the reservoirs greatly exacerbated the damage to houses in West Houston. Specifically, the subevent related to "water release" reflects the emotion of fear for the Houstonians (fear: 1.23).

On August 29, the amount of the discussion about "the water level of bayous and reservoirs" and "the reservoir water release" started to reduce; however, multiple events related to *Flood-control infrastructure* occurred, such as "a levee at Columbia Lakes breached" (fear: 1.47, sadness: 1.31), "a bridge over Greens Bayou collapsed" (disgust: 4.62, fear: 3.04, sadness: 3.55), and "Addicks Reservoir overflows over spillway" (anger: 2.19, disgust: 2.04, fear: 1.74).

On August 30, the volume of discussion on flood-control infrastructures further reduced. Besides the discussion about bayous and reservoirs, one emerging sub-event was that "a van was inundated in flooded water carrying six family members." The emotion score of this casualty event was not significant because most tweets in this subevent used formal and euphemistic language (i.e., fact reporting) without the keywords directly referring to death.

## 2.4 Transportation, casualty, and built-environment hazards

Most tweets in the categories of *Transportation, casualty, and built-environment hazard* were situational information posted by official accounts or automatic tweeting bots; discussions from the public were rare

(Figure 5h). Major topics in the *Transportation* category throughout August 25 through 30 included "road closure," "high water on highways," "airport closure," and "flight canceled."

Tweets in the *Casualty* category (Figure 5i) often contained strong negative emotions due to the keywords in this category (e.g., death and drown). Topics in this category included "report of death tolls" and "news about injuries or deaths."

Similarly, tweets related to *Built-environment hazard* (Figure 5j) also contained high-frequency keywords that were annotated with negative emotions (e.g., fire). Major topics/events in this category were: "apartment fires," "light wire down," "explosion risks of chemical plants," and "bridge collapses."