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CRISIS MEDIA – DISCOVERING SOCIAL MEDIA'S ROLE IN THE EMERGENCY MANAGEMENT PROCESS

A Dissertation in

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ABSTRACT

The use of social media platforms has opened up a new avenue for information gathering by those in the emergency management field. This dissertation examines the use of this new source of information and seeks to add to the Crisis Informatics field of research.

To do so, semi-structured interviews were conducted with members of the Emergency Management community. These individuals play a vital role in the disaster response and recovery process. They have the responsibility of providing information, gathering resources, and coordinating response efforts when disaster strikes. The aim of these interviews was to discover what information these emergency managers believed could be obtained from social media in order to aid in their operations. The coding of the interview transcripts found a set of "information categories" that appeared across the responses of the participants that made up the sample. These categories have been used to describe the types of information the emergency managers indicated as being useful. From there, the categories are used to justify a list of design considerations that future researchers should consider when designing social media analysis tools.

Alongside the creation of design considerations was the development of different prototyped social media data analysis tools. This development was completed to attempt to conduct real time analysis of social media data. These tools utilized the Natural Language Processing methods of sentiment analysis, named entity recognition, and term frequency analysis. When applied to various datasets of collected Tweets, a potential example of event detection was created.

Table of Contents

TABLE OF FIGURES

LIST OF TABLES

ACRONYMS

API	Application Programming Interface
ARIMA	Auto Regressive Integrated Moving Average
BLM	Black Lives Matter
COP	Common Operating Picture
DHS	Department of Homeland Security
EOC	Emergency Operation Center
EMS	Emergency Medical Services
EMA	Emergency Management Agency
FEMA	Federal Emergency Management Agency
GIS	Geographic Information Systems
IBM	International Business Machines
ICS	Incident Command System
IoT	Internet of Things
NER	Named Entity Recognition
NGO	Non-Governmental Organization
NIMS	National Incident Management System
NLP	Natural Language Processing
NPG	National Preparedness Goal
NLTK	Natural Language Toolkit
OSINT	Open Source Intelligence
PSAP	Public Service Answering Point
SMA	Social Media Analytics
USAR	Urban Search and Rescue
USCG	United States Coast Guard
TFA	Term Frequency Analysis

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"My mother would say to me, 'Look for the helpers. You will always find people who are helping.' To this day, especially in times of disaster, I remember my mother's words, and I am always comforted by realizing that there are still so many helpers — so many caring people in this world."

– Fred Rodgers

Chapter 1

Introduction

For as long as crises and disasters have been occurring in the world there have been those who rise to the challenge and respond to them. These responders have utilized many different tools as technology and society have evolved. Despite this evolution, the need for information has remained constant. If a disaster requires a response, the responders need to know what will be required of them to begin mitigating the problem and then aid in the impacted community's recovery. This is true at all scales, from a single vehicle accident to a hurricane impacting a country's coastline. This requirement for information has led to the development and use of communication technologies that enable access to this required information.

These communication technologies play a vital role in the emergency management and crisis response processes. They allow for victims of crisis events to report those events to those who can provide aid, and allow for those responding to coordinate rescue efforts. This transfer of information, from victim to responder, is of upmost importance. The more information available, the more prepared responders can be. As communication technologies purpose built for communicating emergencies, such as the 911 system, developed, social media platforms and internet based communications developed alongside them and begin to become a common part of many different people's daily lives.

The development and adoption of these social media platforms create an interesting opportunity for researchers and practitioners within the crisis informatics field. The ability to capture and examine conversations, reactions, advertisements that gets generated via social media use creates vast datasets to study. For crisis response and emergency management, social media

usage provides another avenue of information gathering to learn more about an area being affected by a crisis.

The real time nature of many social media platforms makes them attractive as data sources for use during crises or emergencies. Content is constantly being generated and conversations are continually occurring and being posed to the social media websites. Emergency management organizations can be aided by being provided the ability to capture, process, and analyze this data.

Examining the Problem

This research seeks to add to the literature that investigates the use of social media data in the crisis response context. This data takes the form of short form text messages produced by different social media platforms. Within this body of literature a number of problem spaces exist ranging from data collection efforts (Peng & Ye, 2021; Mayr & Weller, 2017) to data fusion (Abavisani, et al., 2020). Questions could be asked that inquire into how to target specific types of data and information that make up the content of social media platforms. This dissertation is concerned with the latter problem space, specifically the utilization of social media data and its integration with emergency management processes. Questions are asked that are concerned with discovering what types of information may exist on social media platforms that emergency managers could take advantage of. Not only does this data need to be analyzed and presented, it needs to be done so in a manner that allows these emergency managers to make use of it in real time.

Motivation and Research Objective

This research seeks to build upon work set up by the dissertations of Weirman and Grace ((Weirman, 2019), (Grace, 2019)). Both dissertations ask questions of how social media and the offline world interact and affect each other. Weirman explored the relationship between online engagement and offline mobilization after catalyst driven events (Weirman, 2019). Grace examined integrating social media data into 911 centers and the identification of "hyper local" social media users (Grace, 2019).

Weirman (2019) examines the relationship between online engagement and offline mobilization with the goal of adding to the situational awareness of those tasked with responding to catalyst driven events that resulted in collective offline action being taken. The research was split into two parts, with the first focusing on Network Mental Models and the second on the relationship between online engagement, measured through daily counts of tweets and unique accounts, and offline collective action, measured by the number of participants at a Black Lives Matter (BLM) event.

For the first part of the study, Twitter data set related to BLM events was acquired in order to test the idea of using Network Mental Models to gain situational awareness. This dataset contains messages related to a number of police shootings that occurred from June of 2014 to May of 2015. Variables describing the dataset were created utilizing statistical analysis, content analysis, and sentiment analysis. These variables were tested against each other through the use of time series analysis and ARIMA modeling. A positive relationship was discovered between amount of online content generated and the size of crowds that appeared at events.

Part two of the study focused on the effects that online engagement may have had on offline action. This section of the study took the variables that were generated in part one and tested them against the size of crowds at BLM related events that were driven by police related

deaths. This comparison generally found moderate positive correlations between the twitter data variables and crowd sizes at BLM events.

Grace conducted interviews with those in the emergency response field to understand their social media use (Grace, 2019). This three phase study focused on building context related to social media use, building awareness of generated social media data through various identification methods, and integration of the data into 911 dispatch centers.

The first phase, Context, used scenario-based interviews with the goals of discovering the objectives emergency responders have for social media use, the tasks and resources used by emergency responders related to social media, and the coordinative requirements that emergency responders have related to social media. The studies second phase focused on the identification of hyperlocal social media users. Here, Grace proposed a Social Triangulation method which attempts to identify Twitter users based on reported location in profiles and community organizations being followed by the account. The final phase sought to discover how to best integrate social media into the 911 centers operations. This was done by running a role play and simulation workshop. A Public Service Answering Point (PSAP), or 911 center, was monitored and simulations were conducted with employees. This simulations helped Grace understand that social media information needs to be sought out during emergencies and can't take a roll similar to reactive 911 calls.

Table 1 below comes from the conclusion of Grace's work and proposes future questions that he believe should be examined.

Table 1: Future Questions from Grace (2019)

Questions:
What are the primary use cases for social media monitoring?
What social media analytics do PSAPs require for specific emergency situations?
How should Analysts enter information discovered on social media in CAD systems?
How will collected social media data be stored?
When do direct or indirect reports on social media suffice for emergency dispatch?
Should analysts communicate directly with social media users during an emergency?

To add to these works, this research presented in this dissertation was initiated with the original goal of creating a tool to aid in the decision making process of emergency management personal. This tool would assist with their ability to plan, manage, and recover from disaster events. To do so, information would need to be gathered, processed, and presented in order to create actionable intelligence for those who would be able to make use of it. In order to get to the point that a tool could be developed the needs of the users, emergency managers, needed to be identified. To find this information an interview process was created that will later be described. These interviews were created in order to obtain the necessary information to begin development of the mentioned decision aid tool.

Research Objective

Over time, the project aims shifted from the creation of a tool to the development of design considerations based on the needs of emergency managers. At the beginning of the research efforts two "projects" existed. First, to collect the information required to begin the development of an analysis tool. Second, to go through the product development process and create said analysis tool. It was determined that rather than attempting to achieve both of these projects a better contribution could be made by focusing on the first. By focusing on the first of these projects, a fleshed out set of design consideration could be created and provided to the crisis informatics research community. These design considerations could then be utilized by a number of different researchers who could experiment on the best ways to utilize them to aid in the crisis response process. All of this being said, the overall objective of this research became:

> **To aid in the emergency management process by providing design considerations to influence the creation of social media analytic tools that examine data produced in times of crisis.**

Although the primary focus shifted, some analysis tools were put together as samples to help provide context to the interviews being conducted. These tools allowed the participants in the interview study to gain some insight into some analysis options that exist and to aid in gauging their interest in social media as a data source for their operations.

Motivating the research objective is the desire to aid in the crisis response process. This desire comes from an innate belief that researchers should be aiming to provide tangible assistance to those who operate every day in the fields researchers are studying. Although this particular study may not result in anything that emergency managers themselves will be able to

take advantage of, the hope is that future projects will be able to take advantage of its findings in order to aid those who work in the crisis response and emergency management fields.

Why Emergency Managers

The emergency response process involves many different organizations working together to solve crises. To solve these crises, each organization needs information to achieve their missions. Many different sources of information exist, among them are the various social media platforms that have developed since the late 2000s (Twitter, Facebook, Instagram, etc....). The utilization of these social media platforms to aid in the crisis response processes has been an ongoing topic of interest and focus of research. One of the questions that is important to ask is where in the emergency response process social media data has the potential to provide the most impact. Potential organizations that have the capability to make use of social media data include 911 centers, different first responder organizations (police, fire, EMS), and emergency management organizations. Each of these organizations is tasked with a different mission in the crisis response process and work together to achieve overarching objectives in the goal of responding to crisis events. Of these different organizations, the emergency management groups appear to be best situated to make use of social media data in their operations. This is due to both the nature of social media data, and the nature of the roles these different organizations play.

911 centers and first responder organizations are primarily concerned with short term problems being reported by individuals who need immediate assistance. The information they require to solve these problems will be provided by the individual requesting help and the problem will be responded to and resolved in a matter of minutes to hours. At this time frame, the impact of the problem will likely not be great enough to lead to a response on social media. Additionally, even if there is evidence of whatever incident has occurred, these organizations are

operating at a quick pace and do not have the time to establish processes to monitor social media for useful information.

Operating at a different level and examining different problems are Emergency Managers. These individuals are concerned with the bigger picture of crisis response and the different tasks and processes that go along with responding to emergencies. They have the primary job functions of understanding what resources a community has access to, organizing those resources, and working with peer and higher-level response groups to obtain new resources when needed. Operating at this level provides Emergency Managers with the opportunity to take advantage of new information sources, as they are concerned with crisis incidents that cause impact that will occur over longer time periods and larger geographic areas. The nature of these incidents requires more information that Emergency Managers will need to obtain to be able fulfill their job functions. Social media has shown to mirror offline events (Weirman, 2019) and has the potential to aid Emergency Managers in their operations.

Hurricane Ian

Continuing the thought process of focusing on the needs of emergency responders, this section will provide an overview of an after-action report that was completed on the Hurrian Ian by Lee County, Florida (*Hurricane Ian after-action report - Lee County southwest Florida*, 2023). This overview is given with the intent of providing an example of different response actions that are taken during a disaster event.

Hurricane Ian began as a tropical wave on September 19th, 2022 and transitioned into a hurricane over the course of the next week. It was officially upgraded on September 26th, 2022. The day it was upgraded it was also determined that the Hurricane was moving towards Tampa Bay, Fl. Announcements were made that the Lee County's Emergency Operations Center (EOC)

would activate the next day at a Level One full activation. Bridge tolls were suspended, and county offices were also to be closed over the next two days.

Meanwhile, numerous storm warnings and watches were given to communities along the western coast of Florida. The next morning on September 27th, initial landfall was made by Hurricane Ian around the area of La Coloma, Cuba as a Category 3 Hurricane. Following this it entered the Gulf of Mexico and intensified.

As the hurricane approached Florida the morning of September 27th, Lee County initially opened eleven different shelters and evacuation orders were given for pre-established zones. Later in the day five more shelters were opened and the Florida division of Emergency Management came to the county Emergency Operations Center (EOC) later joined by a Federal Emergency Management Agency (FEMA) official. The County transit system was also utilized to aid in evacuation efforts. During this time, efforts were also made by different response groups to patrol different communities to examine the evacuation progress and attempt to convince those not evacuating to do so.

Initially, landfall was expected to occur at approximately 8:00 PM September 28th, 2022. This estimate was later moved up to 2:00 PM that day. A shelter in place announcement was given at 6:30 PM on the 27th as weather conditions worsened.

By the morning of the day the hurricane made landfall, the hurricane had strengthened to Category 5. Another shelter in place alert was sent out just before 10:00 AM. In the next hour emergency responses by fire, police, and emergency medical services (EMS) were halted. The hurricane made landfall in the United States at 3:05 PM on Wednesday, September 28th, 2022. The initial impact area was the barrier island of Cayo Costa, Florida in Lee County. Afterwards, the hurricane moved on and hit mainland Florida at Pirate Harbor. Later in the evening of the 28th a curfew was enacted due to looting and infrastructure damage and notifications were made that response teams and damage assessments would not be able to be started until the next morning.

On the evening of September 28th, questions were taken from media organizations during a conference, and it was announced that the shelters opened the previous day were less than 10% full. Following the storm four primary categories of actions took place. Urban Search and Rescue (USAR), Infrastructure Stabilization, Mass Care, and Damage Assessment.

The first of these, USAR, began early the day after the Hurricane. Response began to pending 911 calls and initial damage assessments were conducted. It was determined that 98% of the county lacked access to electricity and a few major travel routes were blocked. During the hurricane a backlog of 752 fire and EMS calls was formed which was narrowed down to 26 in the first 36 hours of response. A ferry service was established by the U.S Coast Guard (USCG) to aid in evacuating those stuck in the city of Sanibel, which was one of the impacted areas. Other islands in the area were also evacuated to mainland Florida. In the week after the hurricane a total of 15 different USAR teams had activated and responded to operate in Lee County.

Infrastructure Stabilization activities were focused on restoring infrastructure such as electricity and other utilities. While USAR activities were taking place various utility organizations carried out restoration efforts. Water was reported to be restored by October 2nd and Power was mostly restored by October 7th. Additionally, debris and waste removal was conducted which required managing approximately 12 million cubic yards worth of debris. The USCG also operated to assist in clearing waterways which had been affected by the Hurricane.

Mass care focused on the organization of shelters and POD (Points of Distribution) sites. These activities were aided by the American Red Cross and the National Guard. On September 28th ~6,000 residents were reported to be housed in shelters which dropped to 878 by October 7th. On October 1st when the PODs opened ~48,000 individuals were served, this lowered to ~14,000 by October 7th.

The damage assessment that was conducted found that ~24,000 residential building were damaged and ~4,500 commercial buildings were damaged. This damage led to around $3.22 Billion worth of loss.

Dissertation Structure

The following chapters in this dissertation are structured to both give suitable background information to provide context to the completed research and properly describe the completed research. Chapters 2 and 3 both contain information on existing literature that influences this work and its contributions to the Crisis Informatics field. Chapter 2 focuses on the field of Crisis Informatics, both providing information on research done in the field and some overview on how crisis events are managed in the United States. Chapter 3 starts with the history of emergency response and how data has been introduced into its process. It then moves into discussing a few important research topics relevant to this work. It finishes by explaining the research questions that guided the completed work.

Chapter 4 discusses what research methods were used to complete this work and the tools that provided aid. Chapter 5 is the research study that was completed to answer the research questions laid out in Chapter 3. Chapter 6 discusses attempts at creating some prototype tools that were worked on in parallel with completing Chapter 5's study. Chapter 7 proposes answers to the research questions, and completes the discussion on the contributions to the Crisis Informatics field that have been produced. In Chapter 8 the dissertation finishes with a discussions on various topics including difficulties in the research, limitations of its applications, and recommendations for future work.

Chapter 2

Crisis Informatics

There are many pieces that need to be fit together to understand the academic and practical space in which the research operates. The first of which to examine existing research in the field of crisis informatics. This preexisting research makes up the body of knowledge that this dissertation seeks to add to, and represents the desire of those in the crisis informatics community to aid in the emergency management and crisis response processes.

This research considers Crisis Informatics to be "…a multidisciplinary field combining computing and social science knowledge of disasters…" (Palen, 2016, p. 224). As will be shown later, the work completed for this dissertation fits both the computational and societal parts of this definition. The computing portion includes several different Natural Language Processing (NLP) methods that will attempt to quantify the incoming social media data. Methods from social sciences will be used to learn the most useful ways to leverage that data towards crisis response.

A large portion of the Crisis Informatics field appears to focus on research seeking to understand how social media data is generated and used during crisis events. This research takes various viewpoints, some focusing on data for responders while other examines how the general population used social media during a crisis. To start this discussion, a review conducted by Reuter and Kaufhold (2018) examines the uses of social media during crisis situations. They found a number of crisis situations where social media had been used, starting with the 2001 attack on the World Trade Center in New York City. Other cited events include Hurricane Sandy (2012), flooding that took place in Germany (2013), the Nepalese earthquake (2015), and the attack on Charlie Hedbo (2015). Within these events they found four different categories of social media usage based on who was communicating with whom on social media. These categories are:

citizens to citizens, authorities to citizens, citizens to authorities, and authorities to authorities. These categories should prove useful in focusing the use of social media analytics by building a better understanding of what sort of social media communication data is being examined.

Other work in crisis informatics has focused on individual events. Palen, et al., (2007) conducted a study that sought to understand how information was generated by citizens during the Virginia Tech shooting in 2007. They found that the online communications that were creating this information could be separated into the different Socio-Temporal Stages of Disaster. These stages include Pre-Disaster, Warning, Threat, Impact, Inventory, Rescue, Remedy, and Recovery (Powell, 1954; Dynes, 1970). This helps provide frameworks by which social media data can be studied and its use understood. Another event that generated social media data was the 2013 bombing at the Boston Marathon. In this case, a study was completed that sought to examine offering behaviors that were exhibited after the attack. Lalone, et. al., (2020) found seven different categories of help being offered through use of Twitter. The categories are Shelter, Religion, Family Support, Hashtag Support, Food/Water, Tech Support, and External links. Being able to identify work being done by citizens after some crisis event can provide valuable information to responders as it allows for response efforts to be tailored to what is already being done.

Moving away from data collection and analysis, Giacobe & Soule, (2014), provide a number of recommendations for social media use by Emergency Managers. Included in these recommendations are discussions on general use of social media, EOC command and control, situation awareness development, disaster preparedness communication, damage assessment, and volunteer groups. The overall theme of these recommendations appears to be the creation of processes that emergency management organizations should follow to build a systematic method of social media use. This systematic use of social media would then allow for better examination

of the content produced to aid in situational awareness and communication with the public during emergency events.

Crisis Response Context

In order to more effectively examine social media data and its applications for crisis response, the catalyst events that drive the need for this sort of work need to be understood. These events are the different types of crisis situations that emergency managers identify are required to deal with as part of their job functions. Merriam Webster states that a crisis is “an emotionally significant event or radical change of status in a person's life” (Merriam-Webster, n.d). Building upon this, Canyon (2020) compiles different definitions found in research that relate to crisis creating a new definition which states that a crisis is “An uncertain situation possessing latent risks and opportunities that must be resolved within a given timeframe” (Canyon, 2020 p. 6,). This definition allows for a variety of events to be considered crises, not limiting the definition to “persons” allowing for opportunities to examine events that may not directly involve persons, such as ecological disasters.

After defining “crisis” this section will discuss emergency management. This discussion is motivated by the desire to understand the profession that this research is concerned with. Following crisis events, numerous organizations respond in different capacities and for different reasons. This include police agencies, ems agencies, fire companies, and emergency management groups as examples. As this dissertations research is concerned with emergency managers, what emergency management is should be understood. FEMA considers emergency management to be “…the managerial function charged with creating the framework within which communities reduce vulnerability to hazards and cope with disasters” (Drabek, 1989). .

To start this discussion the National Incident Management System (NIMS) and the Incident Command System (ICS) will be briefly explained. NIMS was designed with the goal of streamlining the incident response and management process. Originally established in 2004, NIMS focuses on the standardization of incident response to aid in the ability for different groups of responders to interact efficiently with each other with they need to operate in the same space. There are three primary areas that are touched on in the NIMS system that include Resource Management, Command and Coordination, and Communications and Information Management (ICS, 2018). The details of these areas are covered in a variety of courses offered by FEMA including IS 700: National Incident Management System, An Introduction; IS 703: NIMS Resource Management; and IS 704: NIMS Communication and Information Management (National, n.d).

Working in tandem with NIMS is the ICS. This system is also an attempt at standardization but in a smaller scale than NIMS. Understanding the ICS is important for this type of research as it is integral to the crisis response process. This process is a major point of study for the crisis informatics field. Ensuring that the processes that currently exist are taken into account when conducting research will allow for more applicable research to be conducted.

The ICS is a set of management principles and processes that exist to aid in the response to crisis situations (National, 2017). There are many different online and in person courses that introduce the ICS to those that seek to use it. These courses are provided by FEMA. Each course teaches a different aspect of the crisis response process and is focused towards different types of personnel.

These two systems support the personnel responsible for responding to a crisis, i.e., first responders. For this dissertation, the definition used by the Center for Homeland Defense and Security will be utilized. This definition states that first responders are “Federal, state, and local governmental and nongovernmental emergency public safety, fire, law enforcement, emergency

response, emergency medical (including hospital emergency facilities), and related personnel, agencies, and authorities" (Staff, 2016). Generally, these responders are dispatched through PSAPs, also known as 911 centers. This makes up the initial response to any potential crisis event or situation. As more is learned about any given crisis different resources are then allocated to the response

As social media analytic tools are developed, understanding where in the emergency response process they fit will aid in said development. This study seeks to discover this as part of its semi-structured interviews. Before speaking with emergency management professionals about the ICS a preliminary search of where social media analysis tools may fit has been done. As part of this search a number of courses have been found that describe parts of the ICS where crisis informatics research may fit. A selection of these courses is provided in Table 2:

Table 2: ICS Courses

Course Code	*Course Name*
IS-29.A	*Public Information Officer Awareness*
IS-42.A	*Social Media in Emergency Management*
IS-235.C	*Emergency Planning*
IS-241.C	*Decision Making and Problem Solving*

These four courses each provide information related to working in the emergency management field. They are provided by FEMA and available on their training website. The first course, IS-29.A, is an introduction to the requirements of being a Public Information Officer (*IS-29.A: Public information officer awareness,* 2019). The course covers material related to preparing an individual to be able to proactively provide information to the public concerning emergency events.

IS-42.A provides instruction on how to incorporate social media into different emergency management processes (*IS-42.A: Social media in emergency management,* 2021). The focus with this course is to provide an overview of the various social media platforms that exist and how

they work, and also providing some "best practices" for how to utilize these platforms. The general theme behind these practices is to provide the public with information related to emergencies through the platforms that are most commonly used. Additionally, thought is given to utilizing social media to identify and combat misinformation that may be generated.

Next is the IS-235.C course. This course examines the planning stage of emergency management and is provided to aid those who need to begin operating in that stage (*IS-235.C: Emergency planning,* 2015). It goes over the different requirements that go into planning, elaborates on steps that need to take place, and aids in evaluating existing plans.

The last course identified is IS-241.C. This is a decision making course that focuses on the decision making process for emergency response personal (*IS-241.C: Decision making and problem solving,* 2021). It examines both decisions to be made before and during an emergency, provides problem solving steps and strategies, and discusses ethics.

PSAP vs. Emergency Management

Differentiating between the roles of PSAP operations and emergency management operations is important to ensure that this research is targeting the organizations that will be able to most effectively make use of it. Briefly, Emergency Management "…is the discipline dealing with risk and risk avoidance" (Bullock et al., pp. 2, 2020) and PSAPs exist to take reports from people who need immediate assistance from either police, ems, or fire services. Making this differentiation is important as these two operations require different types of information and different tools to obtain that information.

Another way of thinking about this difference is to examine the time frames that each entity works in and the difference between "emergencies" and "disasters". To begin, FEMA considers an emergency to be a smaller scale event that can be quickly resolved. Disasters are

events which have grown to require a larger pool of resources than an individual community can pool together (*IS-111.A: Livestock in Disasters*, 2013). In short, disasters take more time to solve than emergencies. The day-to-day work of a PSAP is generally concerned with the former of these two concepts. Most 911 calls involve emergencies that can be addressed with local resources. Emergency managers get involved when more resources may be required, or if the operational period of an incident ends and another one begins. The creation of new operational periods, which is the time scheduled to achieve the objectives of an operation, brings its own challenges (Glossary, n.d). These challenges often require the aid of emergency managers to supplement PSAP systems to bring in resources from outside of the impacted areas. These distinctions are important to note as this dissertations research is mostly concerned with emergency management activities (rather than routine 911 processes), and the types of events that warrant their attention.

Crisis Analytic Applications

As the Crisis Informatics field examines the intersection of technology and society during crisis, it is necessary to be able to extract and examine data from the technology being used. This is generally done through the creation of software and computer applications. These tools allow researchers to study data and information structures during crisis situations. Such tools have been created by both researchers and private companies.

Every tool will have a different focus or use based upon the requirements set forth at the beginning of the project. These tools can be divided into two general categories. The first category encompasses the Data Driven 911 tools. These add more data streams to PSAPs and provide additional information to dispatchers. The second category includes those tools that are geared towards gathering and analyzing social media data related to emergency events.

Data Driven 911 Applications

Examples of a few Data Driven 911 tools include Raven 911, Rapid SOS, and Rapid Deploy (OKI, 2022; RapidSOS, 2022; RapidDeploy, Inc., 2021). These systems are designed to update traditional 911 call systems by adding additional data and information streams. They attempt to aid in the mapping of 911 calls, and the gathering of additional details that may be useful for those responding. By using various types of geolocation and mapping systems these tools help to create common operating pictures (COPs) (U.S. Department of Homeland Security, 2023) for response agencies.

Data Gathering and Analysis Applications

The second category of tools are those that are proactively seeking out information before a 911 call is made. A brief example of such tools is a platform called TwitInfo, which visualizes Twitter data and attempts to identify higher volume time frames in that data (Marcus, et al., 2011). This tool examines data in real time and presents a summarization of the conversations being captured. Others in this category are PIVOT (Elrod, et al., 2021), TAMEE (Giacobe, 2020), Social Feed Manager (Social, 2021), Senseplace2 (MacEachren, et al., 2011), AIDR (Imran, et al., 2014), and CrisisFACTS (McCreadie, & Buntain, 2023). Each of these tools has a different focus as they search for data that makes them useful in different contexts.

Portal for Intermedia Visualization, Overlay and Triangulation

Portal for Intermedia Visualization, Overlay and Triangulation (PIVOT) is a Twitter data collection platform that utilizes geolocation features of Twitter (Elrod, et al., 2021). It is being developed by a team of researchers from the University of Cincinnati and The Pennsylvania State University. The focus of this tool is to collect and map data from Twitter based on the locations

where Tweets are supposedly being generated. There are three ways location is being determined, explicit geotags, user inputted locations, and an implied location based on data collected through bounding boxes.

The tool has an interesting interface that allows users to search a map for Tweets and filter based on keywords and/or locations. This can provide users insight into what sort of discussions are happening in any given area. However, the Tweets are displayed in their full text form with no real analytics being performed. This could lead to issues with users being able to process the amount of information being provided. Only having the text of Tweets can limit what is able to be learned about a situation as it takes time to read through and understand the content of every Tweet.

TAMEE

TAMEE is a Twitter data analysis platform that pulls Tweets from an existing SQL database. The tool will take a time frame from a desired dataset, and perform a number of analytic functions. These functions include word-cloud creation, key-term extraction, a time series of Tweet volume, and a data feed of the text content of each Tweet. This tool is one of the original inspirations for this dissertation. It will provide a foundation and influence for future system development (Tapia, et al., 2015; Giacobe, 2020).

One of the primary limitations of TAMEE is that one is required to manually update the segment of data being analyzed to keep the analysis in real time. It is possible to achieve real time if the database the tool is using is being continuously updated with data, however the user will still need to manually enter new search parameters every time they want new information. This could make it difficult for an analyst to keep up to date with what is being discussed in the dataset.

Social Feed Manager

Social Feed Manager is a social media data collection and management tool (Social, 2021). It has the capability to collect from Twitter, Tumblr, Flicker, and Sina Weibo. It is an open-source platform that connects to the named social media platforms public Application Programing Interface (API). It will create and organize a variety of collections for the user based on the data being collected.

As a data collection and organization platform, Social Feed Manager could be a useful option. However, not having any analytics built in will require users to build or find their own. This can lead to issues with software bloat where analysts have to juggle too many tools to effectively understand a situation they are monitoring.

Senseplace2

Senseplace2 is another social media geolocation tool. It was designed by Penn State's Geovista lab as a situational awareness tool for crisis events. This tool collects data from Twitter, processes and stores it, then visualizes it based on geolocation. Using this visualization, it is intended to aid users of the tool to gain more situational awareness concerning some crisis event being examined (MacEachren, et al., 2011).

Examining the relationship between location and content on Twitter is an interesting concept that Senseplace2 has shown can be useful. As part of the design, emergency managers were surveyed finding that there was interest in information gathering from social media and mapping of that data. They show that the tool can be useful through an earthquake scenario where relief effort monitoring was simulated. However, issues arise with social media tools that primarily focus on geo-located data. MacEachren, et al., 2011 claim that only around one percent of Tweets include coordinate data. This is echoed more recently by Elrod, et al., 2021 who found

that around four percent of Tweets contained coordinate data. Due to the limited amount of data being able to be mapped, issues with loosing valuable information may arise.

AIDR: Artificial Intelligence for Disaster Response

Another tool leveraging the benefits of social media data is AIDR. This tool was started in 2013 by a number of researchers with the Qatar Computing Research Institute. Its primary function is to take messages posted during a disaster and then classify them into various categories. These categories include labels such as needs and damage among others. The classifications are created through the combination of machine learning techniques and the interaction with crowdsourced participants (Imran, et al., 2014). Utilizing this tool are a few papers examining social media use in crisis and disaster response. After using AIDR to collect ~52 Million messages from 19 different crises, Imran, Mitra, & Castillo, 2016 annotated them to train machine learning classifiers. These classifiers were created in the attempt to aid with humanitarian missions. An example of the classification system is given with the nine message classifications created for natural disasters: Injured or dead people; Missing, trapped, or found people; Displaced people and evacuations; Infrastructure and utilities damage; Donation needs or offers or volunteering services; Caution and advice; Sympathy and emotional support; Other useful information; and Not related or irrelevant. Also working on the classification of social media messaging and the use of AIDR for data collection is Nguyen, et al., 2016. This paper utilized neural networks to aid in the identification of both messaging that could be determined informative vs. un-informative and the identification of information types within the informative messaging. Rounding out dissection on work with AIDR is Nguyen, et al., 2017. This work was concerned with damage assessment tasks that take place during disaster response. Attempting to add to AIDR's capabilities, images were collected and human annotators were used to train

recognition models. Three different damage levels were used in the training and recognition, severe damage, Mild damage, and Little-to-no damage.

CrisisFACTS

A more recent addition to tools that examine social media in the crisis response context is CrisisFACTS (McCreadie & Buntain, 2023). Seeking to do more than provide more research for the academic community, the creation of CrisisFACTS sought aid in answering the question "what is happening on the ground" (McCreadie & Buntain, p. 3, 2023) for those responding to emergencies or crises.

The tool that they developed exists as a method to test other frameworks in their ability to summarize text related to different crisis events. This is accomplished by providing various data streams collected from different online media sources that are related to crisis events. The streams are provided in a timeline and are made up of messages that are the lengths of average sentences. These sentences have been processed to contain "important" information. Participants in the CrisisFACTS platforms can use these streams to provide data to their analysis tools for summarization. The summaries produced by the participant's tools are then compared against a standard created by the CrisisFACTS research team. This standard was created through the use of Wikipedia pages related to the crisis events used to create the streams, and reports taken from the NIMS database. They report 23 different participants made use of their system in 2022 and that the performance of these participants systems fell in the 70%-80% range.

Other Work

Adding to research relevant to this dissertation are a collection of papers that do not propose specific data analysis tools but provide other ways of thinking about and examining data

as related to the Crisis Informatics field. Included in these papers (but not limited to) are topics concerned with geolocation the Internet of Things (IoT), and real time data collection.

Examining information dissemination, Mitcham et al., (2021) proposed a communication hub framework that would confront challenges with the outreach of social media messaging. Their framework involves creating a coordinator role within an emergency management group who would be tasked with identifying various community stakeholders. When an event would occur where public messaging would be required, pre-determined information would be shared with the stakeholders who then would share the information with their social media followings. Complementing this work is Rizza, (2023) who examined the integration of citizen-led social media with crisis management. Part of this work included the identification of a horizontal dimension of information publishing; that is the general public giving and receiving information related to crises from each other rather than some "official" source. Also identified was the need to build connections with online communities that can assist with the mobilization of subject matter experts to assist with crisis messaging and data gathering.

Concerning the IoT, Ghasemi & Karimian (2020) discuss various benefits and challenges with the utilization of the IoT into disaster management. As social media use requires many different IoT applications these may also show themselves in its use for crisis response. Each stage of emergency management is provided different IoT applications. Some of these include the use of sensor technologies during risk reduction, the use of simulations during preparation, communication tools for utilization during response, and monitoring technologies to measure recovery. Some of the challenges that they identified include issues with misinformation due to faulty equipment information security issues that are innate in most communication technologies.

Moving towards data collection, Stieglitz et al., (2018) conducted research into issues with topic discover, data collection, and data preparation while conducting analysis on social media data. Included in these challenges were issues with data volume, irregularity, and storage.

Also present were issues with the interdisciplinary nature of social media analytics. Social science researchers lacked some of the computational background to find answers to their questions and computational researchers lacked more grounded theoretical approaches to the use of social media data. Also concerned with data collection, Rachunok et al., (2022) examine Twitter data generated in response to Hurricane Harvey. They examined the effects of different data collection methods such as the use of keywords vs location geo boxes. Their findings indicated that differences existed in the analysis of data based on the collection methods. Based on this, they proposed that data reporting guidelines should be followed that address the data collection, preprocessing, and analysis methods along with the identification of issues that arose during data collection.

Chapter 3

Literature Review

Moving on from research specific to the crisis informatics field, this chapter focuses on a number of different research topics that operate in tandem with Crisis Informatics. The overarching theme of this work falls under the umbrella of Social Media Analytics (SMA). From there, more specific areas of study have been identified which include NLP, Data Mining, and Event Detection. Adding to this are discussions on existing analytic tools and applications. From the qualitative side of research, Semi-Structured Interviewing is also examined. Literature from these mentioned fields has been identified for discussion. The selected works will be used to help justify the research and provide legitimacy to the questions asked.

Before the discussion on the specific research topics begins, it was determined that the history of emergency response, and the introduction of data to emergency response should be examined. These two topics provide valuable background information to the research word and fields of employment that this dissertation is trying to contribute to. The context provided by these topics helps to focus the goals of the research to aiding those who operate in the field every day.

History of Emergency Management

In the United States, development of federally organized emergency management activities has historically been very reactive. Starting in the early 1800's, the first disaster relief act was passed after a large area of Portsmouth, New Hampshire's seaport burned. The U.S congress at the time passed relief funding that was provided to merchants. It wasn't for over 100

years after this event that FEMA was formed April 1st, 1979. Their initial mission was that of engaging in emergency management and civil defense activities. In 1988, the Stafford Act was passed, amending a previous relief act, which provided statutory authority for federal disaster response through the use of disaster declarations by the President. The next major reactionary event was the creation of the Department of Homeland Security (DHS) after the 9/11 attacks. This was a reorganization in 2002 of the United States intelligence organizations which merged FEMA and 21 other groups. Six years later after the devastation of Hurricane Katrina, another reform act was passed. This act took FEMA and made it its own agency within DHS, further defined its mission, and established the FEMA administrator as advisor to the President for everything emergency management related. Following this event, in 2012 Hurricane Sandy caused damage to the East Coast of the United States. The Sandy Recovery Improvement act of 2013 was passed which allowed for tribes that had been federally recognized to request disaster declarations and also simplified some public infrastructure recovery processes. Most recently, the Disaster Recovery Reform Act of 2018 was passed. This act expanded FEMA's authority with the goal of being able to better mitigate disaster through strengthening America's capabilities throughout all levels of government (*History of FEMA*, 2021).

Alongside the disaster events and congressional acts that lead to the creation of FEMA, other organizations were created, or provided instruction, to aid in disaster response within the United States. One of these organizations was the Army Corps of Engineers who, through the Flood Control Act of 1934, was tasked with conducting flood control projects. Two decades later in the 1950s during the cold war, emergency management activities became focused on civil defense due to the threat of nuclear war. During this time agencies such as the Federal Civil Defense Administration and the Office of Defense Mobilization were formed. Although these organizations existed, most emergency management activities were carried out by local civil defense directors. In 1958 these two organizations were combined into the Office of Civil and

Defense Mobilization. Moving into the 1960s, an uptick was seen in natural disaster occurrences. Events such as The Ash Wednesday storm, a 9.2 Richter scale earthquake in Alaska, a tsunami in California, and Hurricanes Betsey and Camille caused hundreds of millions of dollars in damage and claimed hundreds of lives. With these events, funding was provided pieces at a time and no true overarching organization was present. In 1968 the National Flood Insurance Program was established through the National Flood Insurance Act. This act was one of the first times that mitigation concepts began to be considered and concepts such as community-based mitigation were practiced (Bullock, et al., 2020).

Introduction of Data to Crisis Response

Before any response to a crisis or disaster can begin, those responsible for the response need to know what went wrong, where it went wrong, and what they need to fix the problem. Currently in the United States the 911 system is the primary communication route that this information is conveyed. Through the use of PSAP's, 911 calls are taken by dispatchers who then "dispatch" the appropriate resources. This system began with the first 911 call being placed in February of 1968, beforehand it being required to call local numbers (*The History of 911*, 2023). Even before telephones became widespread a need to call for assistance was recognized. In the early 1900's Ericsson Incorporated developed a "portable" phone that was able to attach to telephone wires and then create a signal to be answered. This was reportedly used to call in a train robbery in 1907 (Industry, 2016). Also aiding in the reporting of crisis, in this case fires, were fire alarm boxes. Coming about in the 19th century these boxes would be placed throughout a city and wired through the telegraph system. They could then be used to report a "box alarm" to report the location of a fire based on where the box was located (Tar, 1992).

As technology improved, so did the 911 system. One of the first improvements and a potential beginning to the introduction of "data" was the ability for PSAPs to automatically receive information such as caller address, caller name, and call back numbers. From there, as wireless phone technology developed, 911 systems mirrored the development and built the capabilities to receive this same information from wireless phones. From there the development of VoIP (Voice-over-IP) led to the required integration with PSAPs and the 911 system. Currently, the focus is on the continued development of NextGen 911 which was the goal of allowing 911 calls from all networked devices, the automatic transfer of calls between PSAPs, the standardization of network providers, and the maximization of cost savings/maintenance requirements. Additionally, the ability to provide services such as text to 911 and automatic event notification (i.e. crash notification) are being worked on (Industry, 2016) .

Adding to the data to be potentially utilized by PSAPs is social media data generated during crisis events. This data has the potential to provide information to responders that may be missed through 911 reporting. One attempt at this comes from Tapia, et al., (2015). Their work discusses the proposal of TAMEE, which was discussed in Chapter 2.

Examining social media data as a source for information related to crises matches with the history of how data is introduced to the crisis response process. As technology and communication tools have developed, the 911 system has developed with them taking advantage of new innovations to better gain information about events that require response.

Social Media Analytics

As the core of the proposed research revolves around social media data, it is important to discuss common methods to collect, process, and analyze this data. For this research SMA will be used in order to take the information that is generated by social media platforms and transform it

into actionable intelligence. This process is important, as intelligence is information that has been processed for a specific use (Dupont, 2003). This will be required in order to achieve the goals of this research.

The intelligence creation process starts with data collection, moves to data analysis and finishes with data application (Pellissier & Nenzhelele, 2013). A common way to collect social media data is through the use of APIs, which provide access to a given platform's data. This provides the opportunity to obtain more data than web-scraping as access is given at the source of the data rather than through a front end (Lomborg & Bechmann, 2014).

Two methods are used to conduct the analysis phase. NLP which allows for large amounts of text data to be processed quickly making it ideal for social media analysis and text analytics which gains its use in identifying specific topics being discussed in a dataset (Batrinca & Treleaven, 2015).

Data Mining

One of the first steps needed to transform social media data into intelligence is identifying and gathering the data. Colloquially, the term Data Mining is often used to describe this process. More specifically, data mining can be considered the "…process of extraction of information which is hidden, previously unknown and is potentially useful, from large databases" (Agarwal, pp. 203, 2013). For SMA, this definition works well as we are seeking to find information that has already been created and stored in the various social media platforms being examined. Another way to think about data mining, focusing on its role with social media analysis, is to consider it the act of "…identifying novel and actionable patterns in data" (Barbier & Liu, pp. 328 2011). They also discuss different uses of mining social media data including Community Analysis, Sentiment Analysis, Social Recommendation, Influence Modeling, and

Information Diffusion. Splitting the concept of Data Mining into smaller parts, Jayamaline & Ponnavaikko (2017) discuss the differences between Web Content Mining, Web Structure Mining, and Web usage Mining. The mining used in this dissertation falls into web content mining as it is interested in the different content being produced on social media sites rather than information such as how a site is created or how social media users interact with the sites interfaces.

Natural Language Processing

International Business Machines (IBM) considers NLP to be "…the branch of computer science…concerned with giving computers the ability to understand text and spoken words…" (IBM, 2020). This is necessary for the completion of the proposed research as large amounts of text data will need to be processed and interpreted in near real time.

There are two primary tasks in this work to be performed using NLP methods, Sentiment Analysis and Named Entity Recognition (NER). These tasks will be used to interpret conversations being held on social media platforms. Aiding with these tasks will be N-gram recognition and term frequency analysis. N-grams are word grouping identified in bodies of text where N is the number of words (Kumar, 2017). Term frequency analysis is the identification of how frequently words in text appear (Azam & Yao, 2012). These tasks have been chosen as they have been shown to be applicable to crisis response efforts.

Natural Language Processing Applications

After discovering what sort of information emergency managers want from social media, analysis methods can be targeted. As more is learned about the information needed, proper tools

can be selected. This will help keep the development of the platform focused towards the needs of its end users. It will also allow for better justification to be given to the use of the final analysis methods that are to be used.

The two following NLP methods are a starting point to be able to begin discussions with emergency managers. They have been chosen as they can provide quick examples of what sort of analysis is possible to potential stakeholders in this project. As this research continues and more is learned about what information is needed by these emergency managers, then the types of NLP tools that are to be used can be narrowed down and better defined.

Sentiment Analysis

Two different Sentiment Analysis tools that have been investigated are VADER (Hutto & Gilbert, 2014) and ANEW (Bradley and Lang, 2017).

VADER (Valence Aware Dictionary for sEntiment Reasoning) uses a lexicon that was specifically designed for social media data. It allows for the sentiment of microblog data to be quantified on a scale from negative one to one. This score is based on the presence of words that have been identified as either “positive” or “negative” in emotion/sentiment. Scores from 0.05 to 1 are considered positive sentiment, scores from -0.05 to -1 are considered negative sentiment, and between 0.05 and -0.05 are considered neutral.

ANEW, the Affective Norms for English Words, developed by the Center for Emotion and Attention at the University of Florida measures three different emotional attributes. It examines and rates pleasure, arousal, and dominance in text that is provided to the tool. These ratings are based on the International Affective Picture System (Lang, et al., 1999) and the International Affective Digitized Sounds (Bradley & Lang, 1999)

To date, VADER has been the primary sentiment analysis tool for this dissertation. It exists in the public domain and once it conducts its analysis the results can be simply integrated

with other python tools to allow for some basic graph creation. Its simplicity was the primary motivation behind its use over other sentiment analysis options.

Named Entity Recognition

The entities that are being recognized for this research are generally considered to be words that help answer the "who, what, where, why, and when" questions (Marrero, et al., 2013). A number of tools have been created that implement NER in different manners, some attempting to focus on emergency management needs.

Kung, et al., (2020) propose an NER model that uses three different modules to create their NER method. The first module creates a repository of entities that are related to disaster response. The second uses a bi-directional Long Short-term Memory which predicts the tag that could be given to each word. The final module uses transfer learning to assign entities that have been processed through module two based upon the entities from the first module.

An additional tool that provides NER capabilities is the Stanford Named Entity Recognizer (Finkel, 2005). This program developed by the Stanford Natural Language Processing Group is primarily geared towards identifying Persons, Organizations, and Locations. This makes it useful in the crisis context as it provides analysts the ability to discover who is driving conversations and the topics that are being discussed.

Data Visualization

The ability of obtain, process, and analyze data is only part of the process of creating intelligence. At some point the information being analyzed needs to be presented to those who can utilize it to make decisions. Though there are many ways to visualize data, certain concepts should always be considered. One of these concepts is Ben Shneiderman's Visual Information

Seeking Mantra (Shneiderman, 1996). In his mantra he proposes seven tasks that should be utilized when seeking to visualize data: Overview, Zoom, Filter, Details-on-demand, Relate, History, and Extract. Building tools that utilize these seven tasks should allow for the users to discover what they need to from any dataset. More recently, other visualization considerations can be seen in Evergreen & Metzners, (2013). They believe that visualizations should be simplified to the bare minimum amount of information needed and that design attributes like color, weight, motion, and text/arrows should be used to best emphasize important information. Also weighing in is Midway, (2020) proposing ten principles shown in Table 3 to aid in the presentation of data.

Table 3: Stephen R. Midway's Data Visualization Principles

Principles	
Diagram First	Use the Right Software
Use an Effective Geometry and Show Data	Colors Always Mean Something
Include Uncertainty	Panel, When Possible (Small Multiples)
Data and Models Are Different Things	Simple Visuals, Detailed Captions
Consider an Infographic	Get and Opinion

Aiding in the utilization of these discussed principles/guidelines/tasks are data visualization platforms such as Matplotlib and Seaborn (Hunter, 2007; Waskom, 2021). Matplotlib is a python graphics package that aids in creating data visualizations; Seaborn builds upon it by providing user interfaces to utilize the Matplotlib platform.

Additional Concepts

Aiding in the development of this dissertation are a few concepts that will appear in the final work. Each of these concepts provides valuable context to what this dissertation is trying to

accomplish, and helps provide methods to achieve its goals. They are important aspects of the research that should be understood before attempting to dive into the development of the end product.

Open Source Intelligence

Going along with other crisis analytic tools that have been developed are applications of social media analysis for crisis response. These applications generally take advantage of open source intelligence (OSINT) which is "…intelligence collected and inferred from publicly available and overt sources of information" (Agarwal, et al., 2015, p. 21). Using OSINT allows organizations to obtain information at little cost to themselves as it is all accessible by anyone. As an example of this, Agarwal, et al., (2015) performed social network analysis with the goal of locating extremist content being shared on the internet. They then attempted to use these analyses to aid in predicting civil unrest.

Other examples of OSINT being used can be seen in Neppalli, et al., (2017) and Ragini, et al., (2018). Neppalli, et al., (2017) were interested in reactions towards Hurricane Sandy through the correlation between Sentiment Analysis and Geo-Mapping. This was done to assist in building an understanding of the needs of those affected by the crisis event, aiding in response and recovery efforts. Along a similar vein, Ragini, et al., (2018) also examine Sentiment during crisis events. They examined social networks for types of speech to classify collected data based on the types of assistance needed by those affected by a crisis. More recent examples include an attempt to build a social media analysis architecture (Coche, et al., 2019) and the use of social media for crime investigation (Siriaraya, et al., 2019).

Coche, et al., (2019) proposes a framework to aid in delivering analysis of social media data during crisis to decision makers. To do this, the framework intends to integrate the way

responders obtain and use information into the platform that collects and examines its data. This would be done by processing the collected data in a way that translates it into a commonly used responder vocabulary to assist in decision making.

Siriaraya, et al., (2019) seek to examine social media's ability to assist in the investigation of crime. Through the use of spatial, time-based, word-tagged, and historical event visualization this paper builds a prototype to investigate crime. Each aspect of this prototype is designed to aid users in gaining more information about the crime based on its social media reaction. It hopes to aid investigators with obtaining more contextual information related to a crime.

Event Detection

A critical piece of crisis response is obtaining as much relevant information about said crisis as possible. This information also needs to be gathered and verified quickly. This makes the concept of event detection appealing in the crisis informatics field. The sooner that a crisis situation is identified, the sooner the information gathering process can start. For this research, the data being used to detect events comes from social media sources. These sources provide an additional avenue to find information that is constantly being updated. If useful information from these sources is able to be found, another information resource becomes available to Emergency Managers.

Current work related to social media event detection appears to take many different forms with a variety of methods being tested. These range from attempts at examining the similarity of messages in specific time ranges and geographic areas (Zhou and Chen, 2014), to semantic reasoning with the goal of identifying commonly occurring categories of message types (Li, et al., 2017).

Sayyadi, Hurst, & Maykov, (2009) and Weng & Lee, (2011) have completed work in the field of similarity detection. Sayyadi, et al., (2009) build co-occurrence networks out of keyword pairings that have been identified in collected documents. These networks are then used to find topics being discussed. Weng & Lee, (2011) look for new grouping generation, believing that a sudden increase in discussion of a topic may indicate an interesting event. These methods show that there is validity in examining social media data and that, if done properly, uses for the examinations may be found.

Another aspect of event detection is the identification of sub-events. Pohl, et al., (2012) examined metadata from Flickr and YouTube to identify these events. Word clusters were created that indicated smaller events occurring tangent to the initial crisis situation. This work added to Becker, et al., (2010) who were interested in using clustering social media data based on content annotations. The goal was to use these clusters to then identify potential events.

Working in tandem with event detection work is image recognition. Alqhtani, Luo, and Regan, (2015) do this through the examination of images. Tweets related to the Air Asia Flight 8501 crash were used to train an algorithm. The images were analyzed in conjunction with the tweets and it was found that using image recognition tools added to the accuracy of the event detection efforts.

Adding to the use of image recognition is Jing, et al., (2016). This work examined images obtained from FEMA and flood related Facebook groups with the goal of being able to identify photos that contained flooding. The FEMA photos served as a baseline while the photos from Facebook tested the algorithm on lesser quality photos. The information provided by these methods add to an emergency manager's ability to understand the situation created by a crisis event.

Communications Literature

Alongside crisis informatics literature, is work done in the communications field that has examined how social media is used to communicate during crisis or disaster events. This literature gives credibility to the idea of utilizing social media for crisis and disaster response operations, as it shows that it is indeed being used by the public. This is helpful to examine as it provides context into how social media is being looked at by other researchers, and gives examples of how the public uses social media to react to crisis events.

Beginning this examination Olteanu et al., (2015) identified six different categories of information that appear in Twitter data related to different crisis events. The categories include: Other useful information, Sympathy and emotional support, Affected individuals, Donations and volunteering, Caution and advice, and Infrastructure and utilities. Additionally, they identified six different sources that were providing this information to Twitter. They include, Traditional and/or Internet media, Outsiders, Eyewitness accounts, Government, Non-governmental Organizations (NGOs), and Businesses. Prior to this research, Denis et al., (2014) also examine the different types of information being generated on Twitter during crisis events. They collected data from various online media accounts that belonged to Jefferson County Colorado's Sherriff's office during a time period of flooding in 2013. The types of information they discovered include: Hyperlinks, Online Engagement, Protocol, Public, Rumors, Safety, Services, and Status. Understanding what types of information currently exist, and where that information comes from can help focus efforts when attempting to understand how to utilize that data for response efforts. Further giving credibility to the integration of social media analysis and crisis response, Vieweg et al., (2014) collected tweets related to Typhoon Yolanda and identified tweets that were considered "informative" for humanitarian purposes. Representatives from the UN provided them

with feedback that indicated that the UN could make use of the data to aid in situational awareness and identify time sensitive needs.

Having established the existence of data that exists for capture on social media related to different crisis events, different factors exist that create challenges in utilizing that data (Singla & Agrawal, 2024). Included in the challenges that were found are a lack of regulatory authority, software development and framework limitations, authentication and reliability checking, and physical barriers such as online network failures during crisis events. Also identified were cultural and demographic challenges, where certain population makeups may lead to issues utilizing a standard social media format available to everyone. Of these challenges, the issues identified with software development and the lack of a framework to utilize social media data for crisis response are the most relevant to the research being presented in this dissertation. The identification of a need for a more standardized process helps show the need to continue examining how to utilize social media data for crisis response.

Research Questions

All of the works discussed in this literature review have provided valuable information to the crisis informatics field and have the potential to aid in the crisis response process. They all seek to take advantage of the timely nature of social media data to provide emergency workers and responders with another tool to assist in their efforts.

However, there seems to be a step missing and that appears to be the discovery of what specific types of information are needed and desired from social media by these individuals. Coche, et al., (2019) talk about this in their desire to integrate the processes used by responders into their analysis platform. MacEachren, et al., (2011) also started this process by laying out some high level desires of emergency managers. Further supporting continuing research into

social media and emergency management is Giacobe and Soule (2014) who encourage the integration of local level emergency management and social media analysis tools. This shows that there is interest into this field by emergency managers and that the potential for more to be done exists. This is an important concept that should be expanded on in the field. If the needs of emergency managers are thoroughly understood then analysis tools will be able to more effectively examine social media data and provide aid to emergency managers.

To that end, this dissertation proposes the following research questions:

RQ1: Is there a desire/need for a social media analysis tool?

Before diving into building analysis tools and platforms in the attempt to make use of social media data for crisis response, it is important to ensure that this type of work is actually desired. If there is no drive from those working in the emergency services to make use of social media in their operations, then it becomes incredibly difficult to sell to them the need for a social media analysis tool or platform.

RQ2: How are emergency managers currently using social media?

Understanding what emergency managers are currently using social media for, how they are using it, and why they are using it, will aid in discovering what new tools, platforms, and processes should be added. It ensures that research is being conducted on the right topics and will provide new knowledge to both the research field and provide useful end products for practitioners.

RQ3: When does an accurate and timely social media dataset become useful for emergency management operations?

There are varieties of emergency events that require response. Each event comes with its own information gathering challenges and requires a different approach. Understanding when social media data becomes useful will allow for a better allocation of responding personnel's time and efforts.

RQ4: What information should this social media analysis tool provide?

Having established whether or not emergency managers are interested in social media data and whether or not they are currently using social media data, the next step is to establish what information they expect from social media data. Building this understanding will aid in the development of analysis tools and platforms and help focus what analysis and presentation tasks need to be occurring while examining social media data for use in crisis response.

RQ5: When an appropriate event is identified, what types of analysis tools and processes need to be available for emergency managers to use?

There is no shortage of social media analysis platforms, tools, frameworks, et cetera. These tools are powerful and can be used to learn valuable information from social media datasets. However, every tool isn't useful for every situation and the proper platforms and processes should be identified to provide the most useful information to emergency managers.

RQ6: Who should the tool provide the information to and how should that information be presented?

Once the type of information to be obtained from social media has been identified, that information needs to be obtained and presented to someone. Knowing who your target audience is that will be utilizing the data you are collected will help focus how that data is presented.

Chapter 4

Research Methods

As is indicated in part of the literature review, the field of social informatics seeks to answer questions about the intersection of society and technology. To that end, it is vital that methods that can properly study both aspects of the field are chosen. This leads this dissertation to require the use of both qualitative and quantitative research methods to properly examine the questions it is seeking to answer. Ideally, this mixed methods approach will better justify the findings of the research and its additions to the field of Informatics as a whole.

The primary qualitative methodology for this work takes the form of semi-structured interviews. This format of interview was chosen due to its ability to provide both a consistent format between interviews and the opportunity to examine new questions that emerge during the conversation generated by said interview format. These interviews form the basis for this research,

Working in tandem with the qualitative interview study, is the use of a few different quantitative data gathering and processing methods. These methods include data mining, natural language processing, and data visualization. The use of these methods will be guided by the findings from the qualitative portion of the study. This will keep them focused towards utilizing the answers from the first three research questions to answer the fourth.

Established prior, the goals of this research include providing useful materials to aid in the development of tools for emergency managers to use while responding to real crises. These materials are expected to take the form of design considerations. This mixed methods approach ensures that this societal element of this research is not lost in use of the quantitative methods portion of the work. Leaving out this societal input would be a disservice to the field of crisis

informatics and show emergency response personnel that their experience is not being valued by those conducting research on the field that they have dedicated their careers to.

Qualitative

Many qualitative research methods have been considered to achieve the research objective and provide answers to the research questions. The different methods all come with their own benefits and challenges that make them suitable for this research. Among the methods considered are surveys, simulations, focus groups, ethnography, and various types of interviews. Of these options, the most considered were focus groups, semi-structured interviews, and surveys. In the end it was determined that semi-structured interviews would be the most appropriate method to use for this work.

The other methodologies from the social sciences that were considered for this work include simulations, and ethnography. Each of these plays a role in social science research and can prove invaluable when completing research. At the time this study was initiated they did not seem to be the most appropriate however, there is potential room for their use in the future.

Focus Groups

One of the considered methods, that may become part of future research, was Focus Groups. Carried out by gathering a group of people together to discuss some research topic (Powell & Single, 1996), focus groups allow for researchers to talk with many individuals of interest at once. Often used to illicit more information about a topic, Harrell & Bradley, (2009) mention that focus groups are commonly used as a follow up to previously conducted studies. The method can also be used to help clarify potentially contradictory information.

These attributes made the idea of conducting focus groups for the research presented in this dissertation an attractive option. Aiding in their attractiveness are other works examining social media usage during disaster response and the collaborative nature of the Emergency Management field. This being said, focus groups were not selected as a research method for this study.

The primary reason for this comes from the overarching goal of this dissertation's research. Examining this goal (the creation of design considerations) lead to the decision that speaking with individuals to gain information on their desires would build a better base of knowledge than initially speaking with groups. Being able to have data collected from individuals allows for the examination of similarities and differences in responses. Each participant that produces data can be compared against each other to find out what trends exist across the whole dataset. If focus groups are used, it may become difficult to illicit how many participants had the same thoughts and ideas vs. different ones.

Semi-Structured Interviews

Described as an exploratory interview process that allows for discovery, semi-structured interviews appear commonly in the social sciences (Magaldi & Berler, 2020; Ruslin, et al., 2022). The semi-structured interview has been selected as a method due to its ability to allow subject matter experts to provide insight that a more structured interview may miss. Its nature provides opportunities for the interviewees to leverage their knowledge of the topics being discussed, possibly leading to new questions that were not originally considered. It also allows for the ability for the interviewer to maintain some structure, aiding in the later processing of responses. For this work this will be important in ensuring that the right questions are being asked as they relate to each part of the final platform being designed (Alsaawi, 2014).

A report compiled by the RAND National Defense Research Institute titled “Data collection methods: Semi-structured interviews and focus groups”, provides an overview on qualitative research methods and provides information related to how they should be conducted (Harrell & Bradley, 2009). As implied in the title, recommendations for how to properly conduct semi-structured interviews are provided in the report and help justify the interview procedure that will be examined in the next chapter. Also providing insight into the creation of semi-structured interviews is Adeoye-Olatunde & Olenik (2021). In their work they propose seven different steps to conduct, analyze, and report data from semi-structured interviews. These steps include assessing the appropriateness of the method, sampling and recruitment, designing data collection, conducting the interview, analyzing the data, drawing conclusions, and then reporting the results.

The semi-structured interview processes consisted of several steps. The first was to identify different attributes that would be used to create the sample. Next was the creation of a set of guiding questions. Following this, the sample was identified and contacted. While the sample was being identified and contacted, interviews were scheduled and conduced as participants responded to different advertising efforts. This advertising took the form of making contact with individuals known to the primary investigator, random chance encounters with emergency managers in the public, and the use of Facebook and email listserv advertisements. While the interviews took place, notes and a recording were taken. Following the interview, a coding process was followed where responses from the participant that answered both the interview questions and the overall research questions were identified. Once all participants had been interviewed, each “codes” questions were categorized by similarity and different information categories were created for each code. These information categories were used to provide an overview of the opinions of the participants as they related to the questions asked in the interview.

The question generation process was guided by the goal of finding answers to the overall research questions. This required first building an understanding of how the participants were currently using social media and if it was something they were interested in at all. Once an interest had been established, then questions were asked to illicit responses related to how the participants believed that social media should be used in an information gathering manner, and then who the data would be useful for and how that data should be presented.

Surveys

As a longstanding part of social science research, surveys can often be used in place of interviews due to their nature of being cheap and easy to implement (Dillman, 1991). Used to collect a structured set of data from a group of "cases", surveys often utilize questionnaires to collect answers which are then analyzed by comparing them against each other (De Vaus, D., 2013). This allows for the creation of a data set that can often be easily examined/analyzed to answer questions about the target population/s. A few different formats exist for creating and using surveys in research including but not limited to Computer Administered Surveys, Electronic Mail Surveys, and web surveys (Nayak & Narayan, 2019).

Limiting their use for this research is their more structured nature. Although they may have proved useful in gathering opinions from a potentially larger sample size, the use of surveys may have limited the depth of participant responses. The desire to understand the participants view points on the research topics required a more "in depth" method of data collection. Creating a survey had the potential of losing out on new information that the participants may provide in an interview context.

Future Methodologies

Although not utilized now, there are qualitative methods that should be mentioned due to their potential future use in the Crisis Informatics field. Both simulations and ethnographic research have to potential to provide valuable information about social media use during crisis and disaster events. The ability to observe how practitioners in the field operate and use information gathering tools provides interesting opportunities to gather data to better focus tool development towards their needs.

Limiting their use at the moment is the nature of this research's objective; building design considerations for tool development. This requires that foundational knowledge about the needs of users be found. The running of a simulation or ethnographic study implies that some tool already exists that is being examined; whether it be tested through a simulation or observed by an imbedded researcher.

Running a simulation would involve creating a "fake" environment to test different variables such as Human Factors, Environments, or Technologies (Kessler, et al., 2016). This allows for different situations and/or tools to be tested without potentially impacting the real word and possibly running into moral and ethical issues. The benefit in doing this for Crisis Informatics research is the ability to create a disaster situation without needing to wait for a real one or potentially doing more harm by trying to utilize untested tools to aid in a real disaster situation.

Building on the idea of running simulations is ethnographic research, which could potentially be considered a next step. Generally considered to be "…immersion in the place and lives of people under study" (Wedeen, pp. 257, 2010) ethnography is an incredibly involved process that takes time and dedication. For Crisis Informatics, the ability to imbed oneself in a response organization provides opportunity to learn about how crises are responded to first hand. Additionally, the ability to bring potential information/data analysis tools with you to use can

potentially provide first and data not only in their use by responders, but in their ability to capture real word data. At this time performing such a study may again be limited by the objectives of this research. Baseline information is still being gathered to understand what sort of information is required to produce useful analysis tools.

Quantitative

Operating in tandem with the qualitative research study were different quantitative research methods. These methods were used to produce sample analysis output to use during the interview process and propose some outlined data flow processes that were used to complete some prototyped social media analysis tools. The primary methods used here come from the Natural Language Processing field, as the goal of this part of the study was to summarize and gain insight into text datasets. Included in the NLP methods are Sentiment Analysis, Named Entity Recognition, and Term Frequency Analysis. These methods appeared to be the most useful to quickly examine social media data and provide interpretable information concerned the collected data.

The methods chosen for the quantitative portion of this research were primarily chosen for their ease of use and ability to provide immediate analysis and presentation of social media data. To start, Tweepy was used to identify data from Twitter, capture it, and then transfer it into different databases. Both MySQL and MongoDB were used as there were straightforward tutorials in their use. For data processing, the python package Pandas was utilized as it appeared to be appropriate in dealing with the type of data that Tweets were. To analyze the data the VADER sentiment analysis tool, StandfordNER package, and the python Natural Language Toolkit (NLTK) were used. These there analysis tools appeared built very well for analyzing social media data. VADER was specifically built to examine the short message format of Teets,

the StandordNER was able to identify key entities that exist in social media data (Names, Locations, Organizations, Handles, etc…), and the python NLTK was a straightforward way to examine term frequencies (word clouds and N-grams). The goal in the quantitative portion of this research was not to reinvent any wheels but to utilize existing tools and processes to perform social media analysis in real time.

This goal of achieving real time data analysis also influenced the choice of tools. The code writing process required to use the mentioned analysis tools was very straightforward and allowed for easy modification to utilize the tools in a real time nature. As data was being collected, each tool was tasked with performing analysis on the last "X" number of minutes of collected data. This analysis would then be sent to Matplotlib for visualization. Every "X" number of minutes the analysis tools would then be told to perform the analysis again, and the new data point would be visualized. This lead to the creation of real time data visualizations of sentiment analysis, named entity recognition, and term frequency analysis (word clouds).

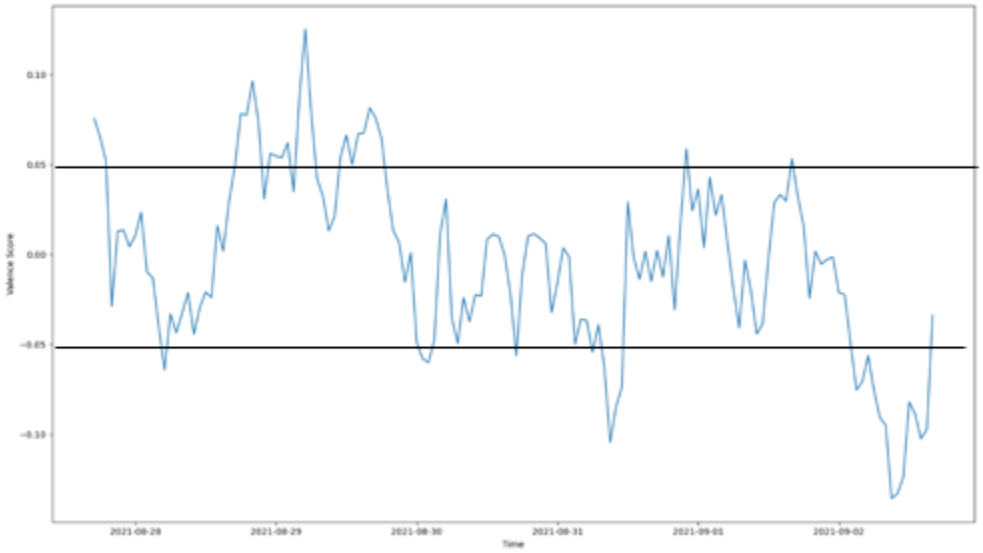
Natural Language Processing

Alongside the use of interviews, different NLP methods have been examined to evaluate their usefulness in assisting with the emergency management process. These methods allow for the processing of large amounts of text data and provide various ways to summarize or quantitate that text data. This may provide emergency managers with helpful information related to whatever event they have been tasked with managing. The primary methods examined include sentiment analysis, named entity recognition, and term frequency analysis. Also considered was the statistical method of ARIMA modeling.

Sentiment Analysis

As described in the literature review, sentiment analysis takes text data and examines the emotions displayed within. For this work, various Twitter datasets were created. The VADER tool was used to process the collected Tweets. This was done both with real time data, with sentiment scores being created as data was collected, and with static data, scoring large chunks of data all at once. In Figure 1 below, an example can be seen of the static sentiment analysis output. The figure shows approximately five days of Twitter data. The data was resampled by hour and VADER was used to create sentiment scores for each minute of data, indicated by the blue line.

Figure 1: Sentiment Analysis Example

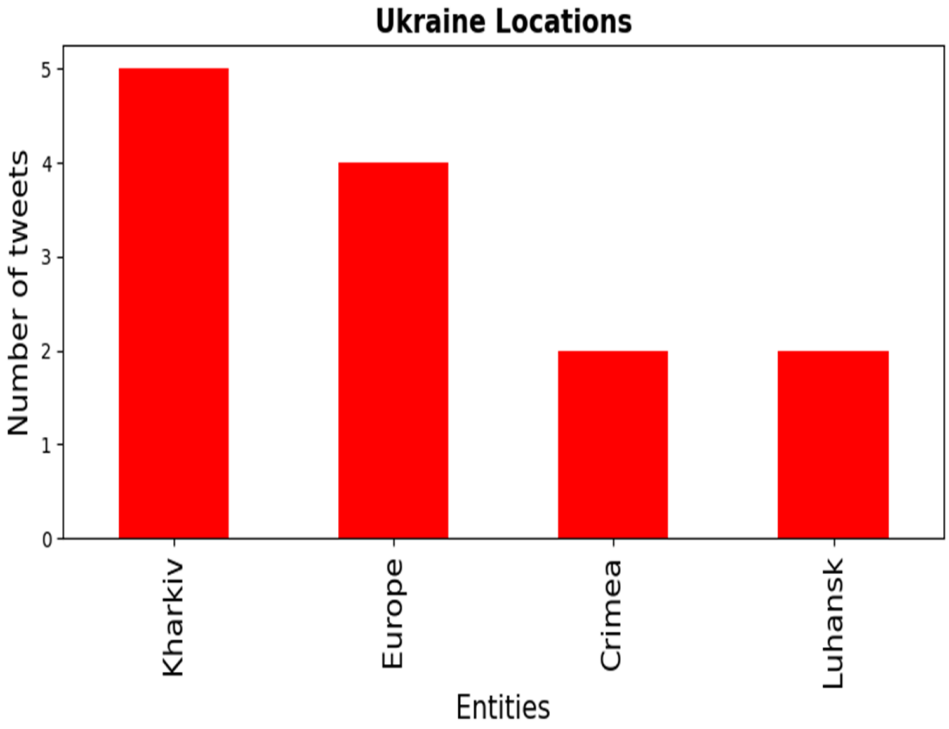


Scores in this graph that fall above 0.05 are considered “positive” scores. Scores below -0.05 are considered “negative” Scores. Scores falling within 0.05 and -0.05 are considered “neutral”. The majority of the data in this figure falls in the neutral category with some positive scores towards the beginning of the timeline and some negative ones towards the end.

Named Entity Recognition

Alongside sentiment analysis is the use of named entity recognition. This task reads through provided text data and attempts to identify "entities" within said text. These entities can be information such as locations, names, organizations, etc…. To produce Figure 2 below, Stanford NER, which was discussed in the literature review, was provided Twitter data related to Ukraine in real time.

Figure 2: Named Entity Recognition Example



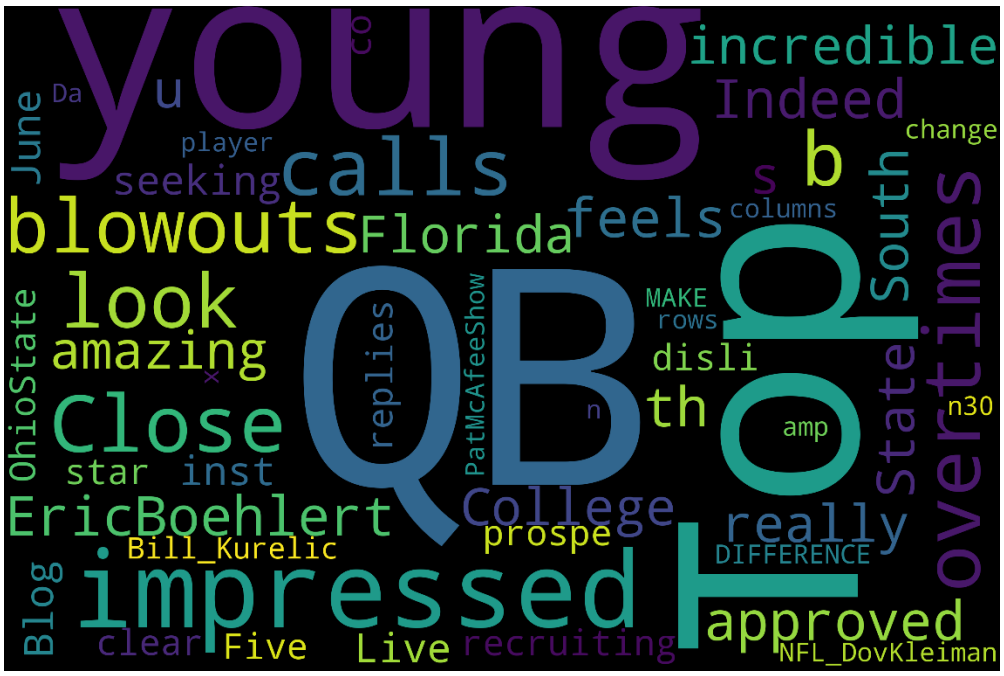
As data was provided to the tool, it identified various locations being mentioned, these locations were then provided to an updating graph generator and the bar graph was produced. The graph would then update as new data was provided to it over a set time period. This time period could cover any amount of time desired, as long as there was data being collected. As the graph

changed, different locations would become more or less mentioned depending on what was being discussed in the collected Tweets.

Term Frequency Analysis

Also aiding in the examination of social media data are TFA processes. Here, collected text data is examined for word usage with the goal of identifying the most frequently used terms/phrases. To conduct this analysis, word clouds and n-gram generation were utilized. Word clouds can be described as "…visual presentations of a set of words, typically a set of tags, in which attributes of the text such as size, weight or colour can be used to represent features (e.g., frequency) of the associated terms" (Havley & Keane, pp. 1313, 2007). N-grams are word parings or groupings that are frequently identified in text (Kumar, 2017). An example of each are seen in Figure 3 and Table 4 below. The data that was used to create Figure 3 comes from a sample set of data being collected that relates to State College, PA and Penn State University.

Figure 3: Sample Word Cloud



The data that was used to create in the N-grams shown in Table 4 comes from a research project were an attempt was made to compare sentiment scores in collected Twitter data to case rates of COVID 19. In this process, the below table was generated which indicated that there were reports of a child who had gone missing in the area the Tweets came from.

Table 4: Sample N-Grams from Doty (2021)

Table 1: N-gram – Oct 12 (N=5)

N-Gram	Frequency
neighborhood, near, ponderosa, dr, amp	75
need, help, locating, 4, year	75
locating, 4, year, old, boy	75
year, old, boy, last, seen	75
help, locating, 4, year, old	75
seen, mount, airy, neighborhood, near	75
old, boy, last, seen, mount	75
airy, neighborhood, near, ponderosa, dr	75
boy, last, seen, mount, airy	75
mount, airy, neighborhood, near, ponderosa	75

Chapter 5

Semi-Structured Interviews of Emergency Management Professionals

Much work has been completed in the crisis informatics field that examines social media data in crisis contexts, such as hurricanes, terrorist attacks, and civil unrest activities. Many of these projects build tools that help collect, process, and analyze the data generated on social media that relates to these events. These tools have the ability to provide valuable insight into the various reactions given by those impacted. Additionally, there is the potential for those responding to the crisis to gain important situational awareness.

Although these platforms do help paint a picture of a given crisis event, there appears to be a lot of descriptive information being presented rather than actionable intelligence. The difference being that information answers who, what, where, and when types of questions. When the information is gathered and presented in a manner that allows for the answering of specific questions to aid in making decisions and taking actions, then intelligence is achieved (Liew, 2013). This research seeks to add to the crisis informatics field by aiding in the process of transferring crisis social media data into intelligence rather than information.

This research seeks to add to the crisis informatics body of knowledge by performing interviews with emergency management professionals. The aim of these interviews is to gain insight into the expectations that emergency management professionals have of social media as a data source. This insight is then to be used to create design considerations for data analysis platforms that utilize social media datasets. Ideally, analysis platforms that have been designed using knowledge from the emergency response field will better integrate into the response process.

A wide variety of interview methods exist and for this research; the semi-structured interview appears to be the most appropriate. As described in the previous chapter, this format of interviewing allows for some flexibility in the process. This flexibility provides the opportunity for new topics to be broached as they come up in the interview process.

Presented in the remainder of this chapter is the procedure used to conduct the semi-structured interviews, with descriptions of the sampling, question generation, scheduling, actual interview, and coding processing being provided. Following this is the analysis of the coded data, and the presentation of the final design considerations.

Interview Procedure

In order to produce the mentioned design considerations an interview process was constructed to target relevant participants and then to start meaningful conversations through a line of questioning. The participants were found through a combination of convenience sampling, snowball sampling and advertisement. The questions were created by deciding what information would be needed in order to make educated claims based on the responses of the participants. This lead to the primary discussion topics of participant background and experience, current social media usage, information needs and desires, and information structuring. Each of these topics had a few questions to help guide the overarching conversation. As each interview was conducted a recording was taken which was then transcribed. These transcriptions were then coded looking for information that would be valuable in creating design considerations for social media analysis tools.

Sampling Method

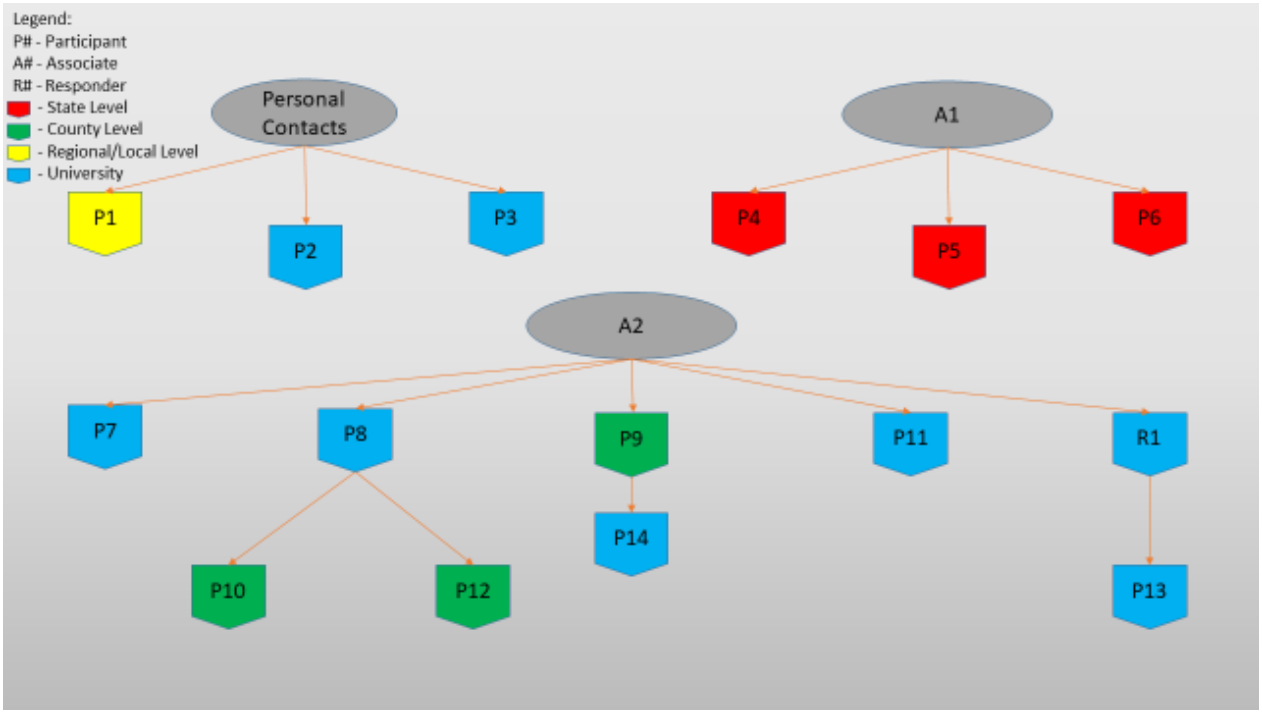
Before any interview could be completed thoughtful preparation was done to ensure that usable data would be collected. This preparation included creating the sample, generating a line of questioning that would create conversation relevant to the goals of this research, and then structuring those questions in a manner that would keep conversation flowing.

The sample was created using guidance from Robinson (2014). In his paper he identified four different "points" that would help guide the creation of an interview sample. These points include creating a sample universe, sample size, sample strategy, and sample source. When creating the sample universe Robinson (2014) notes that it is important to understand your inclusion and exclusion criteria in order to create a homogenous sample. Additionally, types of homogeneity are described to further aid in the creation of a sample universe, these include demographic, geographical, physical, psychological, and life history. The primary inclusion criteria for this sample is that participants have experience working or volunteering in an emergency management capacity. This leads to the homogeneity type of life history, as all participants should share the experiences gained by participating in emergency management activities.

Robinson (2014) sets guidelines for consideration when determining what the size of the sample should be. A differentiation is set between "nomothetic" studies and "idiographic" ones. This research seems to fit within the latter, as it is concerned with discerning the needs of individuals working in emergency management. Operating under this assumption, Robinson (2014) claims that a sample size of 3-16 may be appropriate for studies with idiographic goals. Therefore, the sample size that this work ended up with, 14 participants (over 11 interviews) is appropriate. Ideally, a number of participants closer to 20 would have been obtained but finding participants proved to be more difficult than anticipated.

After identifying the sample source/universe and a goal for the sample size, the sample needs to be identified. The goals of this research lead to the targeting of a specific group of people, emergency managers. This specificity led to the decision to make use of a purposive sampling strategy. To identify and contact these participants a combination of advertising and snowballing was performed. The initial participants were found through personal contacts. From there, advertising was done to reach a wider audience. Finally, referrals were taken from respondents to the advertising. The advertising was done on Facebook and a research group email listserv. The advertisement used can be found in Appendix A. Fourteen total participants were found and eleven interviews were conducted (one of the interviews was done with three participants). Figure 4 shows the sample that was obtained and stratifies the participants based on the level at which they operate as an emergency manager.

Figure 4: A visual representation of the sample



Question Generation

As the sample was defined, guiding interview questions needed to be created to help create a conversation with each participant. It was determined that having a list of questions would assist in creating a productive interview that would provide usable data to aid in achieving the goals of this research.

Table 5 contains the questions that were created. These questions guided the conversation had in each interview and were created and ordered in a manner to touch on specific topics in a specific order.

Table 5: Interview Questions

Guiding Questions
At what scale do you operate at with your organization? Populations size, avg. impact, size of response, etc…
Have you used social media as part of your operations in the past? In what context?
What platforms have you used? How have you used them?
What prompted your use of social media/the chosen platforms?
What potentially interests you about social media as a data source if you have not used it in the past?
What communication directions do you see social media best utilized in?
If you theoretically had access to the whole of social media what would you want to see?
What information gaps have you noticed exist in previous operations?
How would you like this information presented to you?
Who would this information be provided to?
What types of events do you believe this information would be most useful? At what scales?
Which stages of planning/response do you believe social media data to be most interesting/useful?

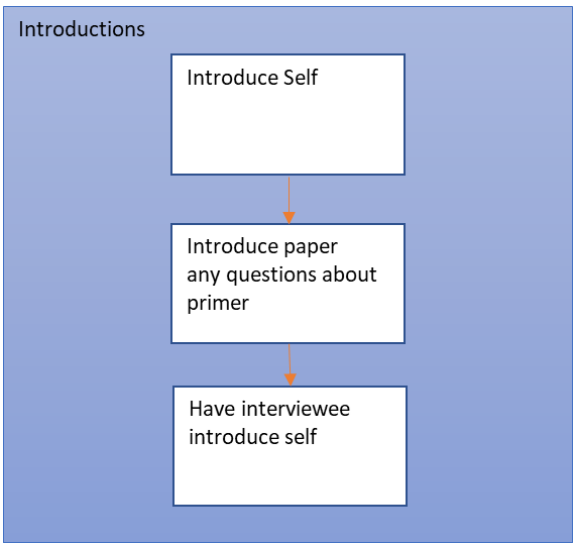
This order was created to allow the conversation to flow in a way that made sense, setting up each topic of conversation to be able to use information that came up previously. The general order of these topics was to first build a background of the participants' current position and their current experience with social media use as part of their operations. Second, to learn about what information they believe would be valuable to obtain from social media. Third, to learn about how to present that information and who it would be provided to.

Once the interviews started, not every question was asked every time exactly as it appears above. As has been mentioned, these questions were created to guide the conversation and elicit responses that would aid in answering this works research questions.

Additionally, a note form and discussion flow chart were created to help guide the conversation and collect data during the interviews. The note form is available in Appendix A. The flow chart sections were not strictly followed but were used to guide the conversation back to relevant topics if necessary. The flow chart had three distinct sections.

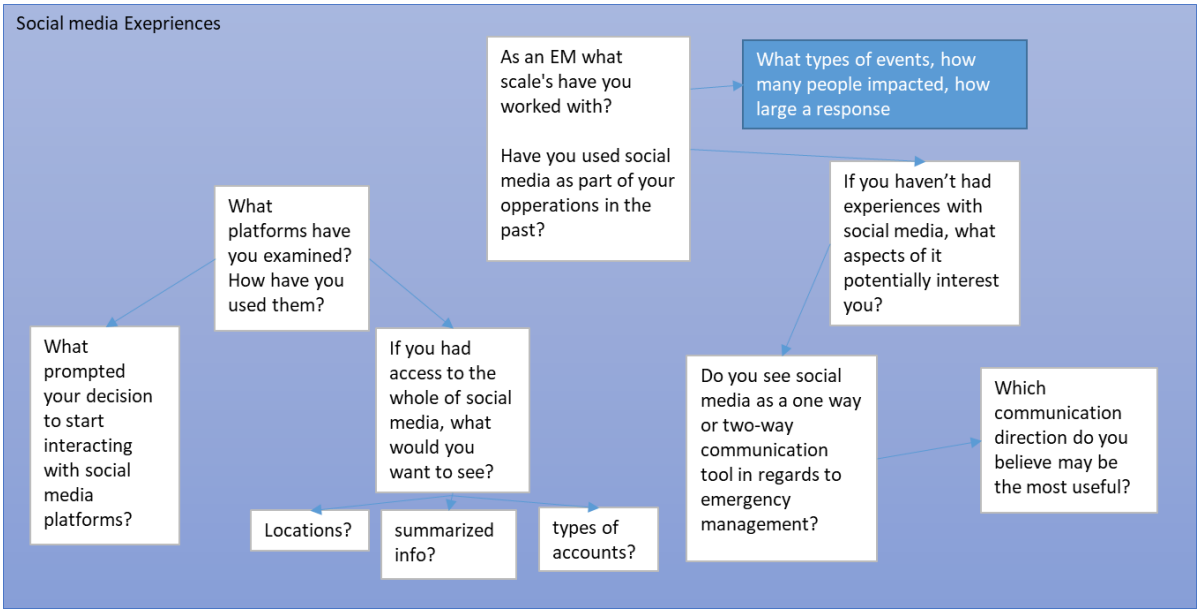
The first section, in Figure 5, of the flow chart goes through the introduction process of the interview. This ensures that the participant understood the aims of the research project and had an opportunity to raise any questions concerning the research.

Figure 5: Introduction Flow Chart



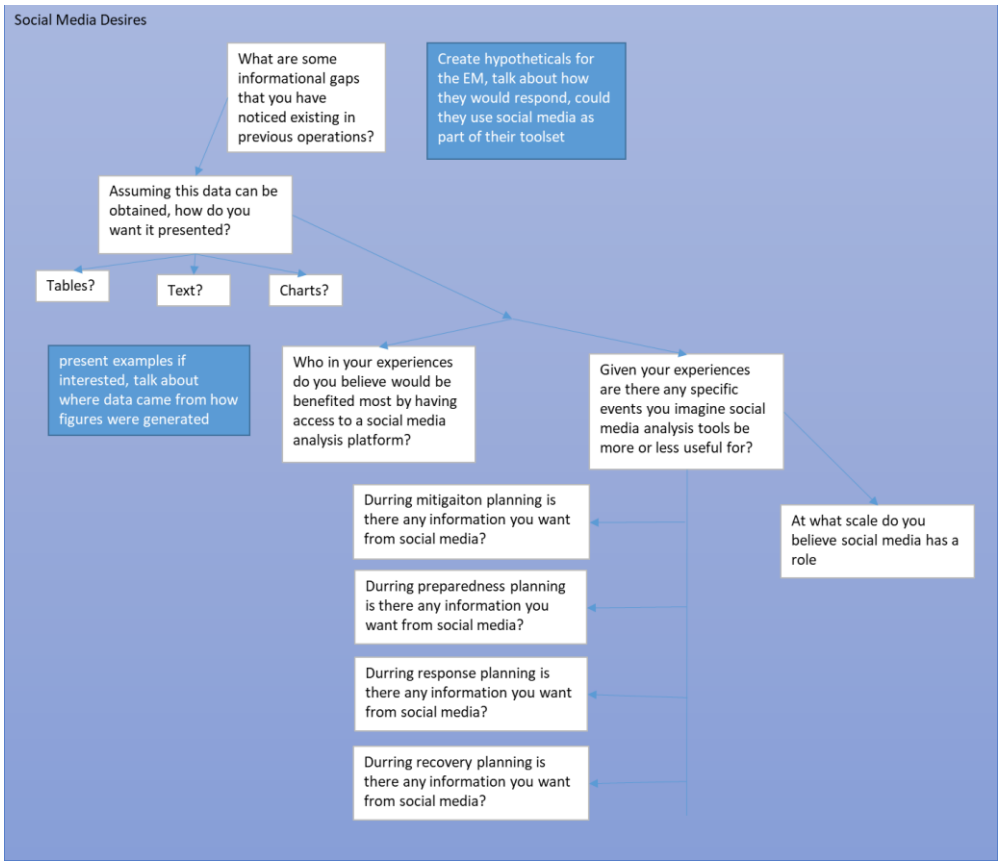
The second section, in Figure 6, covered topics that were concerned with the participants past and current experiences in using social media in their processes. This provided context to later responses and aided in getting the participants thinking about the research space. The final questions in this section were set up to parallel with/transition into the third section.

Figure 6: Experiences Flow Chart



The final flow chart section, in Figure 7, continued with the end of the second and broached topics concerned with how social media data should be presented, who should be using it and when it could become useful.

Figure 7: Desires Flow Chart



The note form and flow chart were designed to assist in keeping the discussion flowing in a natural direction based on the topic order discussed. As mentioned, the aim was to start with discovering background information about the participants to build an understanding of where they come from professionally. This ideally helped provide context to their later given opinions. Following background information, their current uses of social media were examined to be able to then determine how to ask questions about what new information they would like from social media as a data source. Time was also provided to talk through analysis tools that had been created and used as sample analysis methods. These were used to give the participants and idea of what kind of information is available on social media and possible ways it can be interpreted. The figures shown as samples of analysis can be seen in Appendix A.

Interview Scheduling

Once it was determined how the sample would be obtained a few organizational tasks needed to be completed. To better facilitate scheduling and to keep tract of participants, a Google questionnaire and response sheet was utilized. This questioner was sent out with the mentioned advertisements and used to track respondents and their status through the interview process. As interviews with each potential participant were scheduled and completed the response sheet was updated. When an interview was scheduled a short background document and an implied consent form were sent to be read. These documents can be seen in Appendix A.

Conducting the Interview

Interviews were conducted both over zoom and in person. The same process was followed for both formats. Of the eleven interviews that were conducted three took place in person. Participants One, Three, Four, Five, and Six were the in person interviews with Participants Four, Five, and Six being interviewed at the same time (due to participants five and six being added to the interview the day it occurred).

The first task completed at the start of each interview was to ensure that consent for the interview was verbalized. Each participant was asked if they had reviewed the consent form and if they do indeed consent to be interviewed and recorded. All participants consented. After consent was obtained the recording was then started. For interviews occurring over Zoom the built in recording tool was utilized. After the recording the audio was saved to a local, secured, computer and the cloud storage of audio and video was deleted. For the in person interviews the Google Recorder app was used. The recordings were then transferred to the same secured computer and deleted from the recording device.

As indicated by the provided flow charts in the last section, the first part of the interview consisted of introductions and an explanation of the goals of the interview. During this explanation the primer document that was sent ahead of time was summarized to refresh its information to the participant. Following these introductions the guiding questions were asked. These questions were not necessarily asked word for word as they have been provided here. The wording changed based on how other questions have been answered but the general meaning behind each question remained.

As these questions were asked notes were taken to aid in the later coding process. These notes allowed for the transcripts to be efficiently searched when looking for information contained within them. During the later stages of the questioning, usually after the question "Who would this information be provided to?" a brief slide presentation was given to each participant. This presentation can be seen in Appendix A under the title "Interview Presentation" The purpose of this presentation was to provide sample analysis output of social media data to gage the participant's opinion of some potential tools.

At the end of the guiding questions, each participant was asked if they know of any other individuals who may be interested in participating in this study. This information was taken down, or the indication that it would be communicated over email later was given. Following this, the recording was ended.

After the recording was stopped, the participants were thanked for their time and informed that they would be contacted again regarding the outcomes of the study or if any other questions emerged. No participant has been contacted with more questions at this time.

Coding

While participants were being found and interviewed, the analysis of previously collected data. The first step of this analysis process was to transcribe the interviews. This was done using Office 365's transcription feature that is part of its Microsoft Word program. This feature is able to take recordings, transcribe the audio and recognize the speakers and assign the transcribed text to each speaker. This process lead to a total of 273 pages of text that were created from approximately nine hours of interview audio. Following the transcription a coding process was completed. The list of codes can be seen in Table 6.

Table 6: Pre-Determined Code Descriptions

Code	Description
Participant Background	**Responses that indicate the participants background**
Social Media Experience	**Responses that indicate previous social media experience**
Platform use	**Responses that indicate what social media platforms are currently being used**
Social Media Motivation	**Responses that indicate the participants motivation for using social media data**
Potential Interest	**Responses that indicate participants potential interest in using social media data**
Communication Direction	**Responses that indicate the communication directions social media is being used in**
Information Needs	**Responses that indicate the informational needs the interviewees have of social media data**
Information Gaps	**Responses that indicate what types of information the interviewee feels like they do not receive**
Presentation	**Responses that indicate what types of presentation methods would be best for social media data**
Information Users	**Responses that indicate who would use information from social media**
Emergency Management Stages	**Responses that indicate which stage of emergency management social media data may be most useful in**
Scale	**Responses that indicate what scales the participant operates in**

The coding process took two primary steps, first creating a list of codes intended to identify information required to answer the research questions. Then categorizing the findings of

those codes to understand the trends between participants. When filling in data for the first list of codes, the transcripts were read through and key take-aways were formed for each code. As these take-aways were being created, supporting quotes were pulled from the text and assigned to the code with the take away.

Following this, the data was organized by code and each take away was then categorized based on similarities between each codes take away. A sample of the first coding process can be seen in Table 7 and the categorization process in Table 8.

Table 7: Sample Coding Process

Code	*Take-away*	*Quotes*
Background	Regional Emergency Manager	"So, I have an office of one and part-time deputy and a part-time office manager."

Table 8: Categorization Process

Participant	*Code*	*Take-Away*	*Category*
1	Background	Regional Emergency Manager	3
2	Background	University Emergency Manager	4

The end results of this coding and categorization processes is shown in Table 9 in the following section. That table will display all of the different codes and categories that were created.

Descriptive Analysis

The creation of categories during the second step of the coding process was the first look into finding trends in the interview data. These categories allow for a quick look into the data and help summarize the responses of the participants. From these categories trends can be identified.

These trends aid in the creation of design considerations and development concepts for social media data analysis tools.

When creating categories for each code, a range of three to eight categories ended up being discovered based on the generated take-always. Based on the responses from the participants, the take-away's created could fall into multiple categories. This was done so that it can be determined how many times certain ideas came up during the interviews. Limiting each participant to one category of thinking may hide the other ways they think about things, creating an inaccurate representation of ideas when the distribution of categories is examined. After all the categories were created they were then split into two different groups. First being those that belonged to codes that dealt with information relating to the participants existing use of social media and their personal backgrounds; the latter those that had to do with the information they thought should be targeted on social media and how that information should be processed in the future. Table 9 shows an overview of all the created categories. Each set of categories was created by examining the similarities between each participant's answers and the created take-away's.

After all the categories were created they were then split into two different groups. First being those that belonged to codes that dealt with information relating to the participants existing use of social media and their personal backgrounds; the latter those that had to do with the information they thought should be targeted on social media and how that information should be processed in the future.

Table 9: Code Categories

Categories								
Current Experience								
Participant Background	State	County	University	Regional				
Social Media Experience	Information Pushing	Information Gathering	None					
Platform use	Facebook	Twitter	Instagram	Reddit	Discord	Nextdoor	Tweet Deck	Linkedin
Social Media Motivation	Specific events	Increase in public use						
Potential Interest	Sentiment Analysis	Information Pushing	Communication	Already use				
Scale	16,000-40,000	67,000-100,000	400,000+					
Communication Direction	One way in	One way out	Two way					
Future use								
Information Needs	Resources needed	Impacted population locations	Impacted population data	Damage information	Population Sentiment	Misinformation identification	Incident identification	
Information Gaps	Impact / resources	Information timeliness	Communication	Message Outreach	No answer/not thought about			
Presentation	Geographic information systems (GIS)	Reports	Filtered Reports	Graphs	Categorical			
Information Users	EOC Information / Comm. Units	Tailored for everyone	Decision makers	Social media units	GIS units	Planning Units		
Emergency Management Stages	Mitigation	Planning	Response	Recovery	All	Identify Change		

Participant Background

The primary goal of completing these semi-structured interviews was to elicit knowledge about the information needs of emergency managers related to social media data sources. While performing these interviews, much was also learned about the participants' current uses of social media and the different career backgrounds that each participant came from.

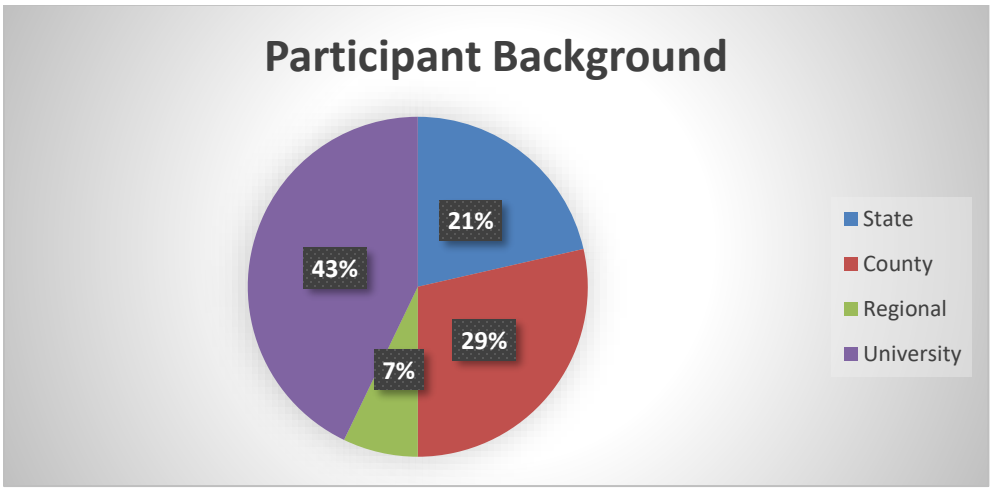
The first set of categories created was for the Participant Background code. This set of categories is rather straightforward, as it describes the level at which the participants office operates. The four categories discovered for this code were State, County, University, and Regional. Table 10 and Figure 8 show the distribution of participants for each category. The state level was made up of those who worked for a state's emergency management offices, the county level for those working at a county's emergency management office, the university level for those working for a college or universities emergency management office, and the regional level for those working in emergency management at a governmental level lower than the county level.

Table 10: Participant Background Category Counts

Participant Background	State	County	University	Regional
Participant Count	3	4	6	1

To divide the participants up, responses that indicated what sort of organization the participant worked for were sought. An example of the type of information used can be seen with participant 11's statement *"So currently I'm the assistant director for Emergency Management at the University of…."* This places the participant in the university category.

Figure 8: Participant Background Categories



Social Media Experience

The next set of categories was for Social Media Experience. These categories are dividing up how the participants currently use social media in their operations. Three categories were created and can be seen in Table 11 and Figure 9.

Table 11: Social Media Experience Category Counts

Social Media Experience	Information Pushing	Information Gathering	None
Participant Count	7	4	5

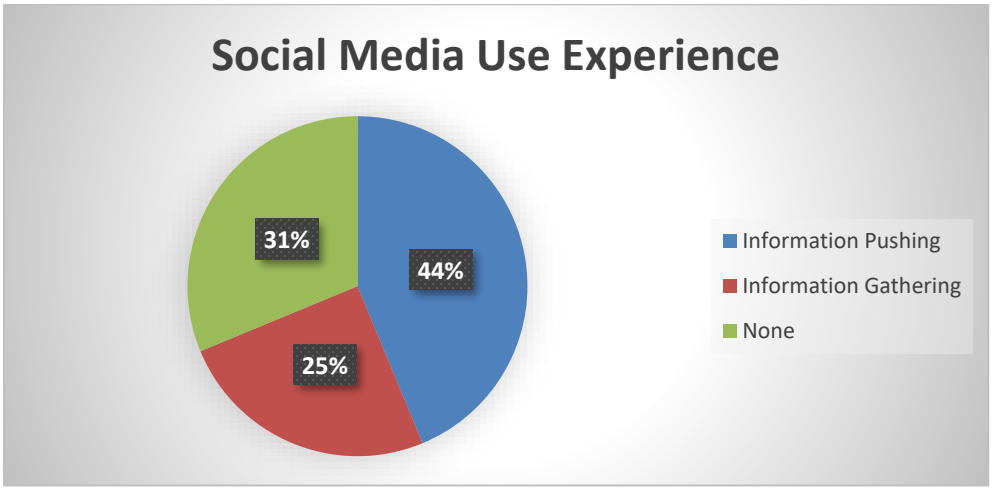
The Information Pushing category was for responses that showed that the participants used social media to send information related to their operations to the public and communities they served. This is seen in responses such as the following from Participant 13 stating *"…So from an Emergency Management standpoint, we have or we use Facebook and Instagram, and primarily for education outreach purposes…"* For the Information Gathering category,

responses such as the following from Participant 10 were used to find participants that actively went on social media to seek information to assist with their operations:

> *I'm monitoring Twitter and Facebook and all the other channels for Intel. When it gets to a tipping point where there's enough valid information out there, we'll start determining if that information can be validated with other information that we get from first responders and that then kind of filters in to our operational plan.*

The final category for this code was "None" or participants who do not currently use social media in any real capacity, or who do not use it themselves but had other groups that may provide information to them.

Figure 9: Social Media Experience Categories



The current experience that most of the participants had utilizing social media data as part of their job functions was focused on pushing information out to the public. This information was primarily concerned with notifying the public of different emergency preparedness information and distributing information related to different crisis incidents that may be occurring. There were also some individuals concerned with monitoring social media for information relevant to them. Types of information being monitored included road closures, weather reports, or events

involving large crowds that may turn into riots. The takeaway from the participants current uses of social media is that they are indeed using it but doing so in a traditional manner. The participants did not make much indication that they are utilizing purpose built social media analysis tools to aid them in their job functions.

Platform Use

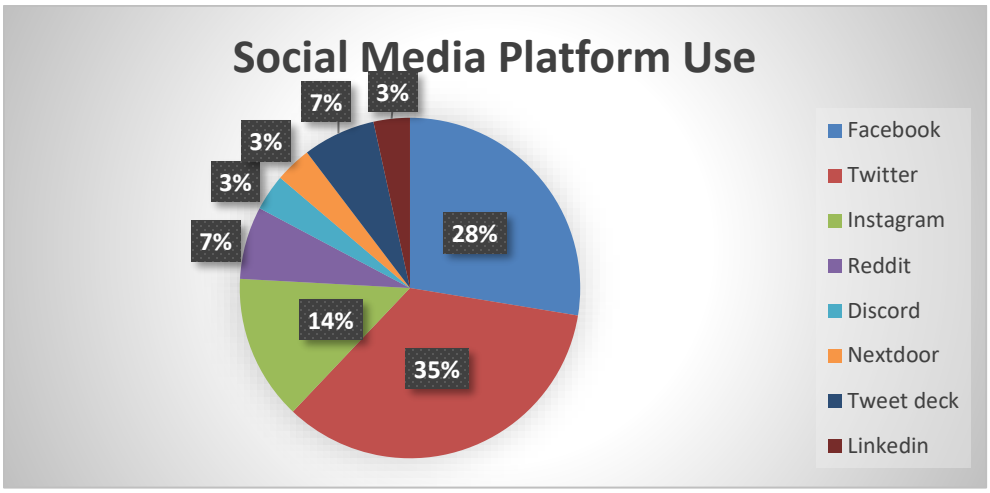
Building on the thoughts of existing use of social media, Platform Use attempts to identify the different social media platforms being utilized by the participants. They were asked what kinds of social media platforms they currently use. Table 12 shows the platforms that were mentioned across the participant pool. Figure 10 shows the distribution.

Table 12: Platform Use Category Counts

Platform use	Facebook	Twitter	Instagram	Reddit	Discord	Nextdoor	Tweet Deck	Linkedin
Participant Count	8	10	4	2	1	1	2	1

Of the eight platforms that came up Twitter was by far the most common platform mentioned followed by Facebook and Instagram.

Figure 10: Platform Use Categories



Understanding what platforms are currently being used by emergency managers allows researchers to better target tools for them. Being able to focus on the platforms that the potential end users are already familiar with can help in the adoption of new technologies and processes.

Social Media Motivation

Continuing on, the next code categorized was Social Media Motivation. This code was looking for responses discussing what motivated or prompted the participant's use, if any, of social media as part of their operations. Table 13 and Figure 11 show the counts and distribution of the two categories that emerged.

Table 13: Social Media Motivation Category Counts

Social Media Motivation	Specific events	Increase in public use
Participant Count	3	7

The first category, specific events, refers to responses that discussed a specific crisis event that began the participant's interest in utilizing social media. These events included an Amtrak train derailment in 2014 and US Airways Flight 1549 landing in the Hudson. Concerning the train derailment Participant 4 stated:

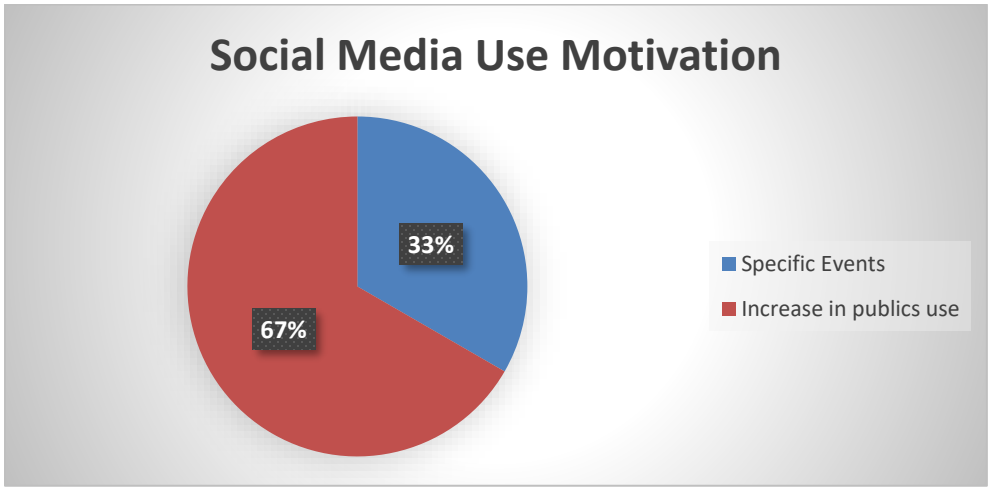
> *I can actually tell you the date that prompted it for us… the Amtrak train derailed in Philadelphia. It was the first time that we actually got a call from. I think it was somebody in the governor's office about an incident that we didn't yet know about… so they hadn't yet reported it to us, but it was out on Twitter*

Detailing the flight which landed in the Hudson River in New York City, Participant 13 stated:

> *…do you remember when the plane landed in the Hudson like 2008 right? Something like that and like one of the first things that went out was like a tweet. Somebody on a ferry boat going to help you know the plane.*

The second category, Increase in Public Use, is for answers discussing how the participant started to engage with social media more as it became more ubiquitous in the world. They discussed how it seemed important to start looking at these new communication platforms as that is where people were talking about what may be going on in the real world. Participant 7 shows this by saying *"…there was no one particular incident that I can recall, it sort of prompted that it just became another way to do public outreach".*

Figure 11: Social Media Motivation Categories



Focusing on why emergency managers began to use social media can help influence the development of tools to aid them. The original interests in social media are going to show themselves in how emergency managers use different social media platforms in the future. By looking back into the original motivations, tool development can be aligned with those motivations.

Potential Interest

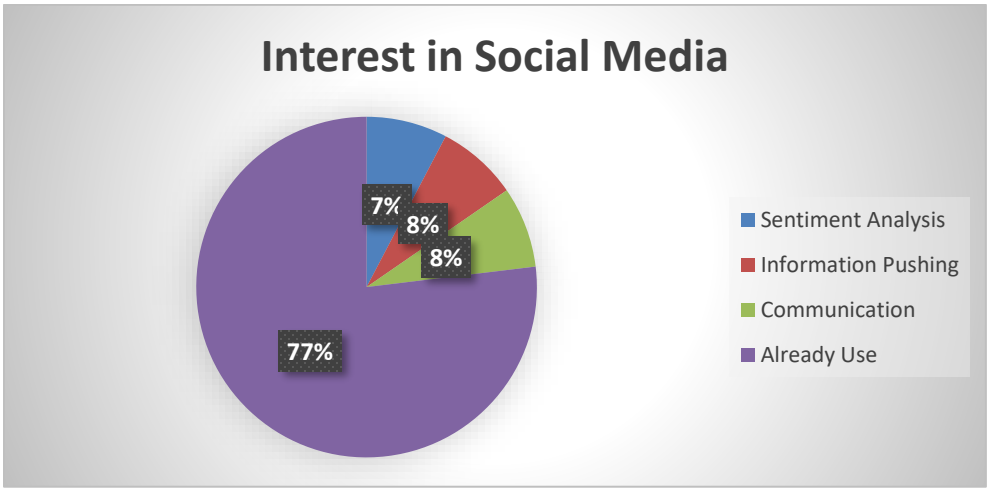
The Potential Interest code was looking for information from participants who had not had much experience with social media but had interest in using it. It sought to find information related to why the participants may want to use social media. Four categories were created: Sentiment Analysis, Information Pushing, Communication, and Already Use. Table 14 and Figure 12 show that most answers indicated that social media was already being used in some capacity. This helps build the realization that not only is there interest in the use of social media by emergency managers, but that they are already actively attempting to make use of it.

Table 14: Potential Interest Counts

Potential Interest	Sentiment Analysis	Information Pushing	Communication	Already use
Participant Count	1	1	1	10

Participant 2 indicated that they would be interested in using social media to gauge the public's attitude towards events. Participant 11 wished to use social media to provide their population with information and resources. Participant 14 talked about using social media to open up two-way communication with their population.

Figure 12: Potential Interest Categories



By showing that most emergency managers in this sample already use social media in their operations, credibility is provided to the efforts to continue research in social media use for crisis/disaster response. If there was no interest in social media use by emergency managers than there would be little point in continuing to research ways to aid them through the use of social media data.

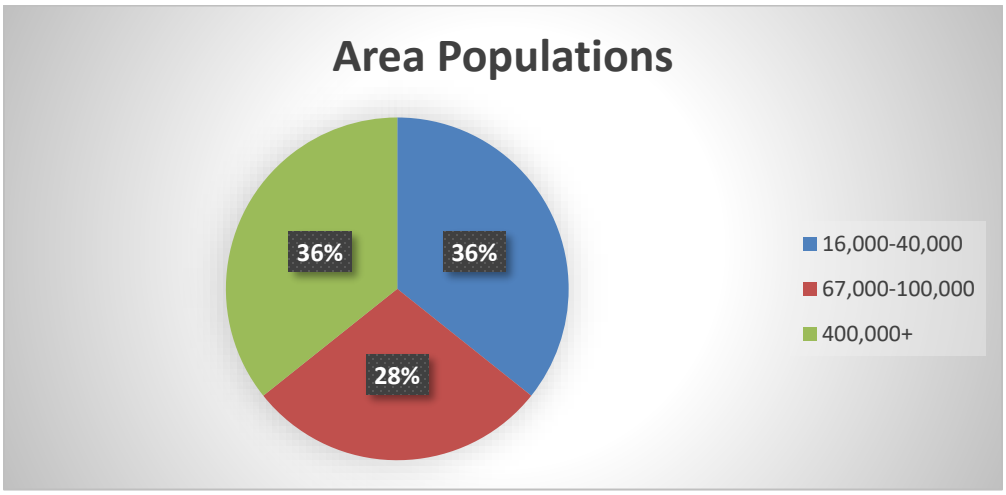
Scale

The next set of codes are a quick description of the population sizes of the areas that the participants worked in. Table 15 and Figure 13 below show the split.

Table 15: Scale Category Counts

Scale	16,000-40,000	67,000-100,000	400,000+
Participant Count	5	4	5

Figure 13: Scale Categories



The first category, 16,000 – 40,000, is made up of one county level participant and four university level participants. The second category, 67,000-100,000, is made up of The 400,000 + category was made up of the three state level participants and two county level participants. The

categories were created through the use of Microsoft Excels data quick analysis function which was used to group the population numbers into the categories.

Communication Direction

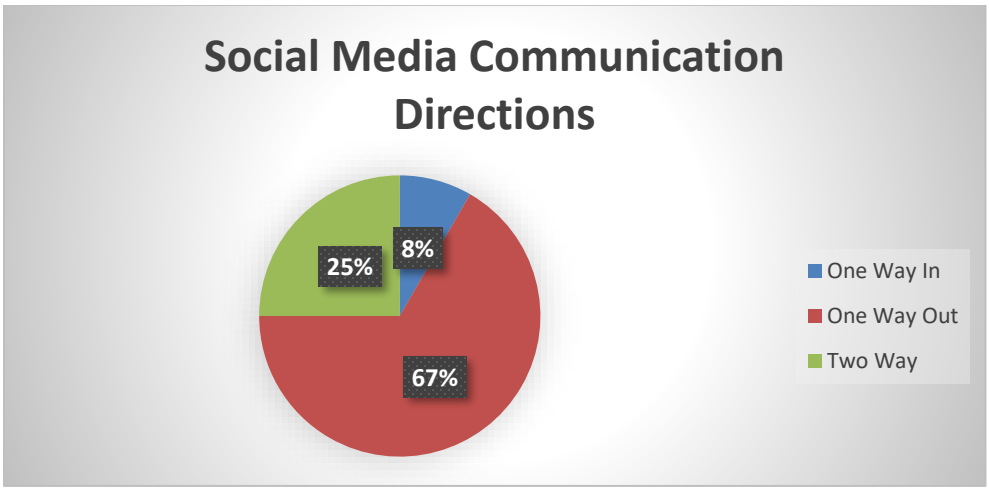
Three different communication directions were identified as being utilized across the participant pool. These categories describe the various ways that the participants talked about how they used social media to communicate with the public. Table 16 shows the categories created, which include one way in, one way out, and two way. Figure 14 displays the distribution.

Table 16: Communication Direction Category Counts

Communication Direction	One way in	One way out	Two way
Participant Count	1	8	3

One way in describes a communication direction where the participant solely received or utilized communications or information from the public but didn't send anything back. One way out describes a communication strategy where the participant would use social media platforms to post information to the public, but would not particularly look at any information coming back in to them. This would consist of activities such as posting emergency preparedness information to a public social media page. Two way communication was for the participants that would both seek and post information or even engage in conversation with the public over social media.

Figure 14: Communication Direction Categories



Much like the previous categories Communication Direction adds to the understanding of how social media is currently being utilized by the participants. Building this understanding will help in future development by allowing researchers to leverage the existing knowledge of emergency managers.

Information Needs

With this next set of categories, the subject matter is moving from information related to how to participants currently use and think about social media to what new information they think may be useful to capture. As its label implies, this code was applied to participant responses related to what information they believed they needed or that could be useful from social media data sources. Seven different categories emerged out of the take-aways from the Information Needs codes. As with the other codes, each category identified and grouped similar responses from the participants through the created take-aways. These categories can be seen in Table 17 with the distributions shown in Figure 15.

Table 17: Information Needs Category Counts

Information Needs	Resources needed	Impacted population locations	Impacted population data	Damage information	Population Sentiment	Misinformation identification	Incident identification
Participant Count	4	3	3	6	3	5	2

The resources needed category was generated based on the participants who wanted to be able to identify what tangible resources would be needed and/or where they needed to go in order to respond to an ongoing event. This is seen with Participant 10's response of *"The idea would be to build an operating picture of where limited resources needed to be sent"*.

The responses for the next category, impacted population locations, were those that mentioned wanting to be able to use social media to identify the locations of those who needed aid or who had been affected by the crisis event. An example of this is the statement *"So that's our biggest fear is the person who needs help, but they're not reaching out"* from participant 7 who was indicating concern with not being able to locate individuals who need aid.

Similar to the previous category is the impacted population data category. This category consists of responses that discussed a desire to learn information about the makeup of the impacted population. Information such as demographics, population sizes, population needs and vulnerabilities is part of the makeup of this category. Curious about the needs of the population in their coverage area Participant 14 says that *"...key information for me (would be) to be able to reach out and say, OK, what are your unmet needs and try everything I can to get those those needs."* Also supporting the creation of this category is Participant 11 who seeks to *"...understand where those vulnerabilities lie and where we may have some insecurities or what are their concerns. Where is it that they don't feel safe?"*

Following this, is the desire for damage information. This category was formed based on answers from participants that discussed an interest in information related to tangible damage that has occurred. Participant 8 indicated this by stating:

> *First reports are always wrong, right? So being able to start building that common operating picture and start mapping where we're hit, you know where we've got trees down where we've got buildings that are that are no longer stable.*

Participant 9 echoed this sentiment with their statement *"How widespread is it? How many homes do we have? How damaged are they? Are there people that are injured? Are there people that are displaced? Are there areas where there's no power?"* Also apparent in this category was the desire to be able to obtain photos of damage. Participant 11 indicated this by having the desire to *"…data mine all the photos…and be able to use people to kind of triage is this a duplicate we can pull it out…"* when discussing tracking a tornado that had come there their area.

Moving away from information about resources and damage is the Population Sentiment category. A few of the participants indicated interest in using social media to try to better understand the impacted populations' sentiment towards various topics. Described simply, Participant 2 stated *"I think one of the things that I'm really interested in is. What's this sentiment around current topics you know current events?"* Going into more detail is Participant 14 who was interested in *"…what the frustrations are and what the needs are so part of our role in Emergency Management is to align resources to help meet the needs of our populations."*

The second to last category is misinformation identification. Along with the potentially useful information that can be found on social media, is misinformation. This information could come from the misinformed or potential bad faith actors. The category was created from quotes such as *"The other thing that is really important is that we be able to get a handle on*

misinformation. As fast as possible as well." from Participant 9. Another example of a response that generated this category is Participant 8 stating:

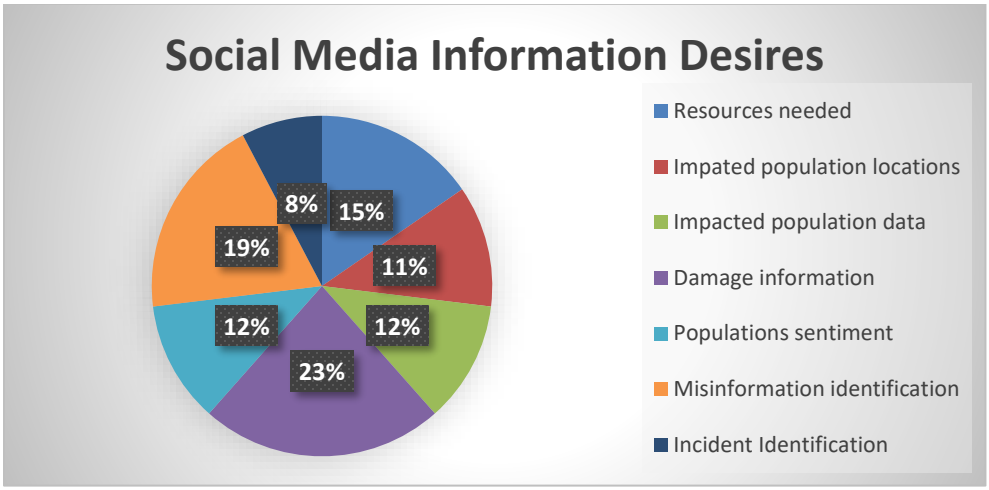
> *And I think the third thing I would want awareness of is where are the rumors going? Where is, where is where the misinformation being propagated. What are people saying that we know is factually inaccurate or being misapplied? Because if we don't know that's happening, we can't. We're never gonna get in front of it, but if we don't know what's happening, we cannot formulate communication strategies to address it and get people correct information.*

The final category is incident identification. The responses that make up this category are those that showed indication the participants wished to use social media in order to identify when some sort of event was occurring that would possibly need a response. As an example Participant 3 mentioned how they would like to:

> *See an initial complaint comes through that says Bristol Ave is blocked. We can't get out. Then you start to see a whole bunch of people say Bristol Ave. and then that. Yeah, I know it's blocked, right? I tried getting out. And you see that trend and at that point you understand you got at least three neighborhoods up there that are blocked in. We got to go deal with that.*

Adding to the desire to potentially identify incidents as they occur is Participant 4. This participant was concerned with identifying multiple events at the same time and stated that any *"…tool needs to provide them the information that says while you're watching that big wreck on I-80, we just had a bomb go off in Pittsburgh, so you need to start watching for that."*

Figure 15: Information Needs Categories



These different information needs should be the driving force behind the development of analysis tools. This category represents the different pieces of information that the participants stated would be potentially useful to obtain from various social media data sources. Being able to provide this information would give emergency managers more insight into the events they are monitoring allowing them to make better informed decisions.

Information Gaps

The next code that was categorized was information gaps. This is somewhat similar to the last set, but is more focused on what information emergency managers have found to be missing during their operations. There is some overlap with these categories and the categories created for Information Needs. The five categories can be seen in Table 18 below with the distributions displayed in Figure 16.

Table 18: Information Gaps Category Counts

Information Gaps	Impact / resources	Information timeliness	Communication	Message Outreach	No answer/not thought about

Participant Count	4	2	2	2	5

The first of these categories is Impact/Resources. This category was created after finding responses that indicated that the participants noticed a lack of information related to the specific impact a crisis event is having on the population. Participant 10 stated that they had trouble finding where *"…the big gaps are. When there is damage? Finding out exactly where that is."*

The next category is information timeliness. Created from responses such as Participant 14's statement *"I think it's the timeliness of getting the information. I think we do good, we get the information we need, but it just never seems like we can get it fast enough…"* These participants noted issues with getting information about the event they are concerned with in a timely manner.

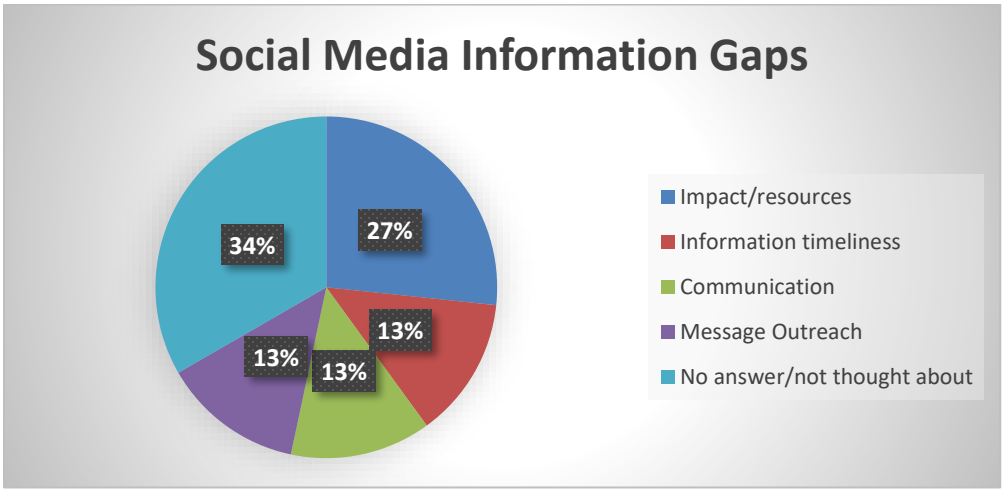
The communication category was created from participants that discussed having issues communicating and understanding the public and other organizations during response efforts. In context of a riot/celebration situation Participant 8 discussed how a *"…photo can't tell us is what the mood of that crowd is. Is this celebratory, you know, are they are they p***** off?"*

Following this, and along the same lines of communication, is the message outreach category. A few participants indicated they wish they could have a better idea of how their messaging efforts were reaching the populations they were supposed to. Putting it succinctly Participant 9 stated:

> *But one of the things that we were struggling to figure out when we had our tornado last year is why aren't people getting the messages that we're putting out there? So we had resources set up for the disaster survivors. We had a whole Resource Center. And had. Access to our board partners that had access to mental health counseling, all these great resources available, and we were running into survivors 5 days in seven days in 14 days in that had no idea what resources were available to them.*

The final category for this code was made up of participants that hadn't really thought about the information gaps they may have and the participants that indicated that they had trouble figuring out the "unknown unknowns" There was a consistent response that it is difficult to try to figure out what information you don't have access to when you don't know what information may be out there. Claiming that there isn't time in the process to think about the things not known, Participant 13 said that *"so much of what we do in Emergency Management is dealing with the problems at hand, not necessarily having time to think 'man, I just, I really wish that I had this information or that information.'"*

Figure 16: Information Gaps Categories



These information gaps work alongside the information needs. Most of the information needs categories are already pieces of information that emergency managers have access to through other sources. Social media use would just provide another avenue to obtain this type of information. Being able to provide emergency managers with information that they do not currently have easy access too would be a great addition to any analysis tools or platforms being developed for their use.

Presentation

Moving away from information gathering, are the categories created for the Presentation code. These categories describe the different presentation methods that where brought up by the participants when asked about how they would like social media information provide to them. The categories can be seen in Table 19 and the distributions in Figure 17.

Table 19: Presentation Category Counts

Presentation	GIS	Reports	Filtered Reports	Graphs	Categorical
Category Count	6	2	2	1	3

The most commonly mentioned presentation method was the desire for the information to be integrated into a GIS tool. This seemed to be due to an existing use of GIS platforms in the Emergency management field. Participant 7 claims "…I think GIS has become so integrated into Emergency Management to try and visualize data in a different way is hard." Participant 11 backs the desire for mapping with their statement "Ideally I want a map of all the issues… I want a map that data mines everything. That gives us a visual representation of where stuff has happened".

Next there were responses that desired different forms of reporting. Some wanted these reports in a condensed manner where the information had already been processed and the report contains specific information for the emergency manager. Participant 10 said they wanted something that would tell them "…the top five important things that we know. Here are the top five things that need to be responded to."

The other type of reporting mentioned were filtered reports. These participants wanted reports that they would be able to use to process and examine the collected information themselves. Participant 9 desired the information provided to them in a way they could rearrange

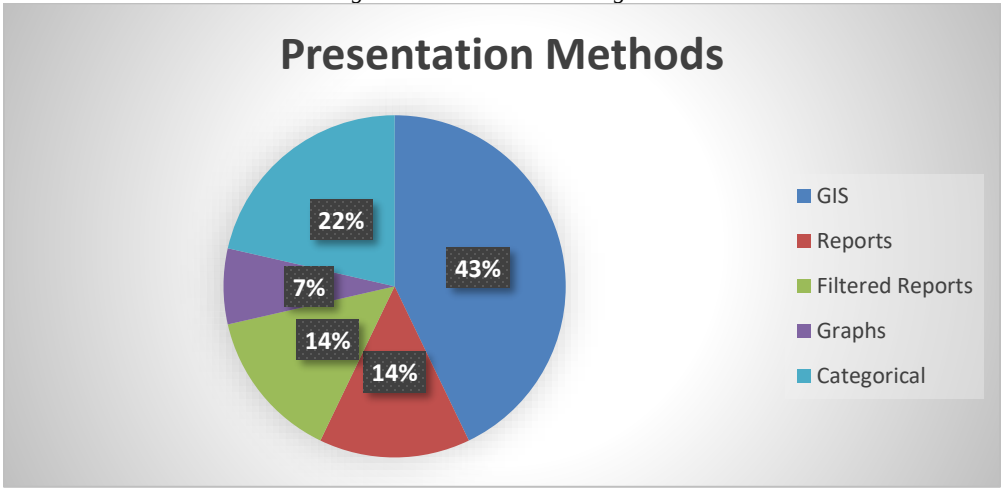
and filter. They wanted something "…not in a static format that I can't work with and can't manipulate and can't transfer into another document or into another platform or into a GIS layer."

There was one Participant who mentioned a specific desire for graphical representation of the data. This category was created for this desire, however graphs would likely be used in order to facilitate the creation of the other mentioned presentation methods. Through the way the questioning was completed this was likely implied in the conversation and not something that was mentioned as a specific desire.

The final category for the presentation code is Categorical. This category emerged from the participants who wanted the information split up based on what type of information has been collected. Participant 2 states that:

> *…A lot of times what we need to do is have it broken down in the categories and be concise, okay? And I think you would almost need to have the categories designed by those who are dealing with the incident at hand…*

Figure 17: Presentation Categories



Being able to obtain useful data from social media is only one step of the process of providing it to emergency managers. Next, is the requirement to provide it to them in a way they can interpret it. The different presentation methods identified in the transcripts are potential ways to do so. Providing new types of data in already used presentation methods has the ability to aid

in the users' interpretation and use of the data, making it more likely they will find use in any new analysis tools and procedures.

Information Users

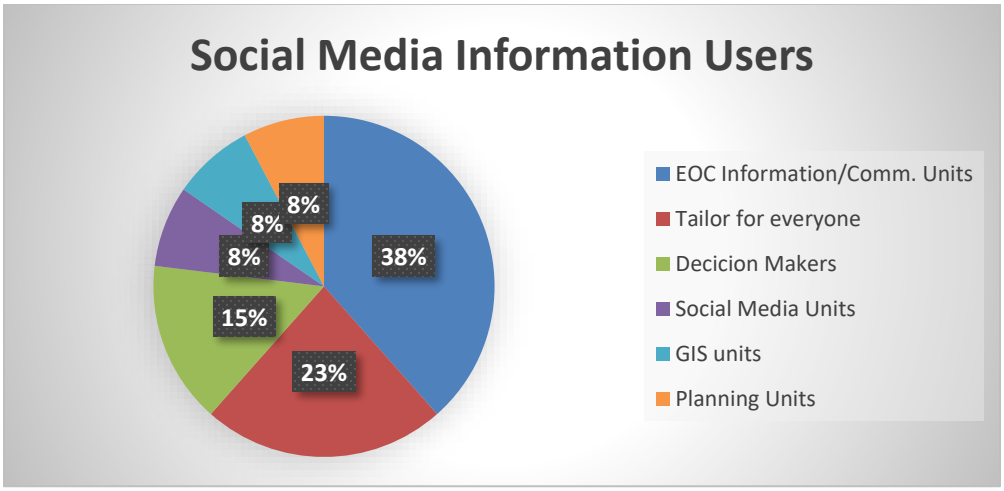
Once the desired information has been found and "presented" it needs to be provided to someone who can use that information to start making decisions. This set of categories comes from the Information Users code. The six categories can be seen blow in Table 20 with Figure 18 displaying the distributions.

Table 20: Information Users Category Counts

Information Users	EOC Information / Comm. Units	Tailored for everyone	Decision makers	Social media units	GIS units	Planning Units
Category Count	5	3	2	1	1	1

First, and most common, are responses claiming that the most useful user of the information would be those operating as part of the Information/Communication units in the EOC. These participants believed that the social media data should come into these units and then dispersed to those who can make use of it. Participant 1 stated that "…when we have an emergency operation center open, and we are, or trying to have that two-way Communication. Then we want that to come into the information center, we want them to analyze it and then push it to whoever needs that."

Figure 18: Information Users Categories



Following the initial category, are those participants who believe that social media analysis tools should be tailored for used by anyone. They believed there was enough information available on social media that, depending on what was being collected, different individuals could make use of it. Participants 4 and 5 both discussed this. Participant 4 mentioned how "in our 67 different counties…I won't say you'll get 67 different answers, but you'll probably get at least a dozen different answers of how that should work in their…processes"; Participant 5 echoes this by claiming that a tool should be "…collecting all the data, putting it in context. Right, but putting it in context, that is a unique context to the end user, right?"

A few participants believed that the information gathered from social media should be provided straight to those in charge of making decisions. When asked about who should be examining the analysis of social media, Participant 7 made the statement:

> *…I think it wouldn't make a whole lot of difference if it was my university IT or a local or state, you know, Emergency Management center. You know the people in the room who are going to make decisions about what are the problems we have to solve, right? They're the ones that need to see that.*

The final categories have one response each and they are social media units, GIS units, and planning units. This variety in responses rather than any consensus may come from the differences that exist in the ways each participant's organization operates. Showing this, Participant 9 states "…we actually do have a situation unit leader position that is supposed to be basically that data gathering point and then turning around and data presenting or, you know, making those visual aids". Participant 8 wants social media use to be "…one of the functions in the situation units." Participant 10 believed that you "…have to be able to target it almost at a planning unit. That has an intelligence gathering segment to it. "

Ensuring that tools are developed for the right users will assist in the adoption of new technologies. Being able to show that a tool has been designed with the end users' needs in mind gives it more credibility. This credibility then can lead to more interest in the utilization of the tool, which should be the end goal of any development of tools to aid in the emergency response process.

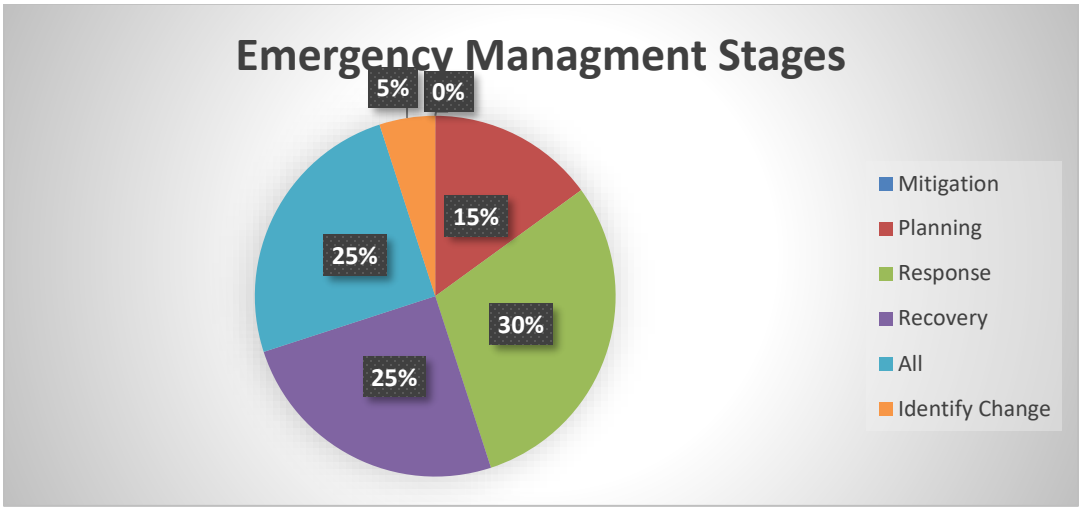
Response Stages

Following thoughts on who should be using social media data is the Emergency Management Stages code. This code sought information related to when in the emergency management process the participants' believed social media data would provide the most use. Most participants believed it was useful in more than one stage and that each stage had its own different use of the data. Table 21 shows the categories and Figure 19 shows the distribution.

Table 21: Emergency Management Stages Category Counts

Response Stages	Mitigation	Planning	Response	Recovery	All	Identify Change
Category Count	0	3	6	5	5	1

Figure 19: Emergency Management Stages Categories



First, there was a lack of interest in social media use during the mitigation stage possibly due to the nature of crisis events existing in a space of the unknown. It is difficult to set up information gathering tools when you are unaware of what information you need to be looking for.

The planning stage was discussed as being useful for notification efforts with social media. Participant 12 states that they believed it was be useful to … Notify(ing) the public of what's coming." Also discussing its use in preparedness was Participant 13 who said that social media is useful for "…sharing social media preparedness tips, which is kind of how we're using it now just from the Emergency Management Office."

For the response stage, responses were looked for that discussed how social media could be used to assist in the tangible response efforts of emergency managers and first responder agencies. Participant 7 showed this with the belief that social media would be useful "that response and recovery phase and more response than anything probably."

The recovery category was established based on participants who believed that social media would be useful post event when recovery activities were occurring. An example of the participant responses creating this category comes from Participant 1 stating:

> *I think from the standpoint of the most useful is on the recovery side…. Our problem on the response side is that we're late. We don't have the ability to press the social media buttons fast enough to get information out there.*

Many participants held the belief that social media played a role throughout all stages of Emergency Management. Putting it simply when asked, Participant 11 said "Oh, I think it has application across the board." There was one response that had the unique idea that social media could be used to identify when the need existed to change from one emergency management stage to the next.

Further Examination of Information Categories

An important step of the research process is to ensure that any analysis conducted is reasoned soundly and has credibility. Continuing this research theme of taking information from current emergency response organizations this section justifies the creation of the presented information categories through finding other works desire for similar information.

The creation of analysis tools to aid in the emergency response process should take into consideration the current manner in which response organizations operate. As this work had discussed, there are many different guiding principles that are used by emergency response organizations. One of these "systems" is FEMA's National Preparedness Goal (NPG). This goal states that the United States should be:

> *A secure and resilient Nation with the capabilities required across the whole community to prevent, protect against, mitigate, respond to, and recover from the threats and hazards that pose the greatest risk (*National Preparedness Goal, 2023)

This provides an opportunity to examine the details of the goal and how FEMA states it should be completed and integrate the work done here to understand social media data's role in the emergency management and response process. Table 22 is extracted from the National Preparedness Goal and lays out five Mission Areas and the Core Capabilities that are required in order to achieve the stated goal.

Table 22: FEMA's Core Capabilities by Mission Area from the National Preparedness Goal (Homeland Security, 2015)

<table>
<tr><th>Prevention</th><th>Protection</th><th>Mitigation</th><th>Response</th><th>Recovery</th></tr>
<tr><td colspan="5">Planning</td></tr>
<tr><td colspan="5">Public Information and Warning</td></tr>
<tr><td colspan="5">Operational Coordination</td></tr>
<tr><td colspan="2">Intelligence and Information Sharing</td><td rowspan="3">Community Resilience
Long-term Vulnerability Reduction
Risk and Disaster Resilience Assessment
Threats and Hazards Identification</td><td colspan="2">Infrastructure Systems</td></tr>
<tr><td colspan="2">Interdiction and Disruption</td><td rowspan="2">Critical Transportation
Environmental Response/Health and Safety
Fatality Management Services
Fire Management and Suppression
Logistics and Supply Chain Management
Mass Care Services
Mass Search and Rescue Operations
On-scene Security, Protection, and Law Enforcement
Operational Communications
Public Health, Healthcare, and Emergency Medical Services
Situational Assessment</td><td rowspan="2">Economic Recovery
Health and Social Services
Housing
Natural and Cultural Resources</td></tr>
<tr><td colspan="2">Screening, Search, and Detection</td></tr>
<tr><td>Forensics and Attribution</td><td>Access Control and Identity Verification
Cybersecurity
Physical Protective Measures
Risk Management for Protection Programs and Activities
Supply Chain Integrity and Security</td><td colspan="2"></td></tr>
</table>

The table gives a framework from where we can begin to think about how to use the codes and their categories to provide design considerations for tool development. Fitting in the desires of social media learned from the interviews into the different Core Capabilities can begin

the process of understanding how social media data can aid in the operations of emergency managers.

Of all the different categories of information that have been generated, the Information Needs category best fits with Core capabilities listed above. A brief description of where each of these categories may fit can be seen in Table 23 below.

Table 23: Category Integration with Core Capabilities

Core Capability	**Information Need**
Public Information and Warning	Info push
Screening, Search, and Detection	Incident ID
Community Resilience	Sentiment Analysis/Build Rapport
Risk and Disaster Resilience Assessment	Two way Communication
Threats and Hazards Identification	Incident ID
Environmental Response/Health and Safety	Damage Info
Mass Search and Rescue Operations	Population Locations and Data
Situational Assessment	All information need categories
Economic Recovery	Resources Needed
Health and Social Services	Resources Needed
Housing	Resources Needed
Natural and Cultural Resources	Resources Needed

The Core Capabilities, which come from different mission areas listed in Table 22, represent those that appear to have the ability to be assisted by the utilization of the information categories created from the interview data. Each capability has a description provided in the National Preparedness guide that lends itself to the possibility of integration with social media data sources and social media information uses.

Public Information and Warning

To start, the Public Information and Warning Capability, which is used on all of the mission areas, seems to be a good place to think about how social media can be used to push

information to the public. The NPG describes this capability as the ability to inform communities about potential threats and hazards that they may face, and what is being done to confront those threats and hazards. From the results of the interviews it is seen that this is already being done by a majority of the participants.

Screening Search and Detection

Fitting in well with the Screening, Search, and Detection capability is the information category of Incident Identification. Part of the Prevention and Protection mission areas, the Screening, Search, and Detection capability is concerned with identifying potential threats to populations. Activities to conduct this work include monitoring the world for these threats through various screening and detection technologies. From the social media side, the interviews indicated that the participants were interested in being about to add incident identification to their abilities. Being able to aid emergency managers with identifying when a crisis or disaster may occur seems to fit with the concepts in this capability.

Community Resilience

Moving to the Mitigation mission area, is the concept of Community Resilience. This capability seeks to build a communities ability to encounter disaster/crisis incidents and be able to respond to and recover from them. This includes assisting in the ability to build mitigation plans and to build proper decision making capabilities to confront potential incidents. To aid in these efforts from the view of social media analysis tools, consider the ability to use social media to build relationships with community members. Ensuring that the general public is aware of and on good terms with those responsible for disaster response can possibly aid in getting the public the help they need. The ability for the public to be aware of the resources available to them allows them to better utilize those resources. Additionally, keeping an eye on the reactions of the public

on social media to response efforts can allow the response personal to check on whether their efforts are being focused in the right areas. Generally positive reactions could indicate that the responders and operating in the right areas and meeting needs and the opposite could indicate that adjustments need to be made.

Risk and Disaster Resilience Assessment

Also part of the Mitigation mission are is the core capability of Risk and Disaster Resilience Assessment. Focusing on conducting risk assessments that identify various threats and hazards to a community, this capability seeks to aid decision making to reduce risk and build resilience. The potential of social media to open two-way communication channels can aid in these assessments by giving community members avenues to voice concerns concerning their ability to withstand disaster. This two-way communication channel allows for emergency managers to build rapport with their communities so that when disaster strikes the relationship between community and responder exists so that the efforts of the responders are expected.

Threats and Hazard Identification

The next Mitigation core capability is Threats and Hazards Identification. As indicated in its name the NPG discusses this capability as seeking to "Identify the threats and hazards that occur in the geographic area; determine the frequency and magnitude; and incorporate this into analysis and planning processes so as to clearly understand the needs of a community or entity" (NPG, 2009, p.12). Fitting nicely with this capability was the identified desire to use social media data to identify incidents that require attention from Emergency Managers. This ability to identify potential incidents through the examination of social media data adds another tool for Emergency Mangers to use in their operations.

Environmental Response/Health and Safety

To start discussing the Response mission area, the Environmental Response/Health and Safety capability encourages taking actions that protect the public, workers, and the environment from potential hazards. Recommendations such as informing workers about these potential hazards and providing resources to protect them, limiting exposure to hazards, understanding potential environmental impact of hazards, and focusing on taking steps to limit the damage these hazards can cause to the environment are given. Focusing social media data gathering and analysis efforts on identifying specific damage caused by the incident can potential provide valuable information to aid in this capability. Understanding the different types of damage can help focus resources to better protect workers by giving them to tools they need to face the damage. Additionally, potential environmental impacts can be identified by knowing the specific forms of damage that have occurred.

Mass Search and Rescue Operations

Continuing in the Response mission area, the Population Locations and Data information category fits with the Mass Search and Rescue Operations Capability. Being concerned with identifying those who need rescued after a disaster this capability seeks to utilize various methods to quickly save as many lives as possible. The ability to use social media to help build information concerning who is being impacted by a disaster and where they are gives these responders another tool in their tool box to use to achieve their mission.

Situational Assessment

Fitting in next is the Response capability of Situational Assessment. This capability is concerned with providing decision makers information that is required for them to properly

understand a situation and begin to make decisions concerning that situation. Primarily focused on ensuring that life-saving efforts are begun as soon as possible, this capability requires information from a variety of sources properly inform the decision makers. This capabilities innate desire for information makes it especially relevant for aid from social media data sources. The various information needs categories identified from the interview transcripts all have the potential to assist in building out his capability. Any information about a crisis has the potential to be useful for a decision maker and the desire for information presented in this capability opens the door to allowing social media data to be examined.

Recovery Mission Area Core Capabilities

The next four Core Capabilities identified as being able to be assisted by social media data come from the Recovery mission area. These capabilities; Economic Recovery, Health and Social Services, Housing, and Natural and Cultural Resources are all concerned with tasks and activities that need to be completed after a disaster incident has occurred. These capabilities also share the social media use category that appears to be most apt to assist in their execution. The Resources needed category should be able to lend a hand in gathering information required for all four capabilities.

Economic Recovery focuses on restoring businesses and other economic assets to their pre-incident state. This is to be done in a timely manner and be integrated into planning done pre-incident. Health and Social Services focuses on the overall health of the impacted community. Specifically ensuring that health care capabilities are operating as needed and that the populations that have been impacted have been identified so that aid can be provided. Housing examines the requirements that exist to provide shelter. This capability aims to provide temporary shelter when needed and to solve problems preventing permanent shelter from being established. Last, Natural

and Cultural Resources seeks to establish planning to protect culturally significant resources and limit damage to natural resources.

As with all of the core capabilities discussed, these four all share the need for information to make informed decisions to carry out their goals. Fitting in with these capabilities, is the information category of resources needed. Becoming evident in the interviews, the need to know what resources will be required to respond to a disaster is vital in order to begin response and recovery efforts. For these capabilities, being able to identify what will be required to begin recovery in each case is invaluable. Adding a social media data source to assist with this identification could aid in emergency managers ability to plan for these recovery steps.

Design Considerations

Following the completion of data coding, analysis, and validation; design considerations can now be discussed and presented. These considerations are based around the findings from the semi-structured interviews and have been created to aid those attempting to build analysis platforms for use during crisis/disaster events. To begin, several overarching tends exist throughout the analyzed data that need to be considered. These trends then lead themselves to considerations to be considered in tool development.

Table 24 provides a short overview of some of the key trends identified throughout the interview and coding process. These trends were identified through examining the different information categories created from the interview transcripts and the quotes that were found to create those categories. The goal of these considerations is to summarize what has been learned from the interview process and to hopefully provide some thoughts to guide those seeking to build social media analysis tools to use during crisis response.

Table 24: Trends to Considerations

Trends	Design Considerations
Different users of analysis tools have different information needs	Focus on the End User
Needs of social media change as a disaster develops.	Focus on the Stage
The desired use of social media changes the reporting and presenting requirements	Focus on Reporting Needs

Focus on the end user

The goal of developing tools to be utilized to aid in disaster response should be to make the jobs of those working in this field easier. The first question that should be asked when deciding to initiate a development effort should be "who is my intended user and what do they need". This is true in other fields when it comes to product development and it remains true for emergency management. This focus on the end users' needs will make the goal of aiding them more likely to be accomplished.

Potential end users include individuals that range from decision makers to lower level analysis in various functional units. These units include, but are not limited to, those working in GIS, Planning, Communication, and Social Media. Each one of these potential users are going to have different needs and uses of social media data. Decision makers are going to want condensed information summarizing what has been learned from social media so that they can utilize then information to direct resources. Unit members may require less generalized information and want to examine analyzed data in order to provide reports to the mentioned decision makers.

Focus on the Stage

Throughout the interview research study, when discussing the topic of when social media becomes useful, it became evident that the popular opinion was that it had applications across the entire process. Also evident, was that these applications changed based on where in the emergency management process social media was being considered for use. Just as the information needs from traditional sources change as the events of a crisis or disaster develop, the uses and information needs of social media data sources changes.

Planning

When discussing the use of social media needs during planning, the focus seemed to be on providing information to the public concerning disaster preparedness. These activities appear to already be done by many emergency managers. Additionally during this stage, there was interest in focusing social media efforts towards learning about the community and identifying potential vulnerabilities, hazards, and threats.

When thinking about designing analysis tools to utilize social media data during this stage, a potential goal could be to build an understanding of what the "status quo" state of social media looks like. Creating a baseline state of social media data during "blue sky" days where nothing of interest is occurring allows for changes in the data to be noticed. These changes could be indicative of some sort of event that should be examined. The Ukraine test case's sentiment analysis graph shows an example of this occurring. A shift in sentiment data can be seen in the graph, and that shift aligned with real word events. This can also be seen in the word clouds created as part of the Penn State test case, where a change in discussion topic was identified lining up with an announcement made by The Pennsylvania State University.

Response

The social media needs during the response stage of emergency management are focused on information gathering. In order to respond to disasters or crises responders need to know what the problem is and where the problem is. Part of the emergency management role is to keep track of different situations developing. Having the ability to gather information about a disaster or crises has the potential in aiding emergency managers in this role.

During the interview coding process, different categories of information were identified as being of particular interest to emergency managers. The targeting of these information categories should allow analysis tools to become useful. The categories generated from the information needs code, originally presented in Table 17, provide examples of specific types of information that should be considered.

The most prevalent of these categories was Damage Information. Targeting information related to damage that has occurred due to some disaster or crisis event provides directly actionable information to decision makers. Being able to provide information to emergency managers about damage that has or is occurring would be invaluable. The sooner that damage is identified the sooner the proper resources can be dispatched. Pairing with the need for information concerning damage is the need for the locations of the damage/those impacted by it and what resources are needed by the impacted populations. An important part of the traditional 911 system is the identification of those calling 911. Without knowing where and what kind of help is needed, it is difficult to provide appropriate assistance.

The next most supported information need was Misinformation Identification. The identification of misinformation on social media allows emergency managers to begin to combat false claims. The existence of misinformation introduces to potential to cause secondary harm to those being impacted by a disaster. Not understanding the truth of what is occurring damages

people's ability to take proper measures to protect themselves. By having the ability to detect misinformation, emergency managers can attempt to conduct damage control and push out accurate information and alert others to the misinformation that is present.

Appearing alongside these first two information needs categories were those that were concerned with the makeup and opinions of an impacted population. Knowing the demographics of the population being affected by a crisis can allows emergency managers to predict possible preexisting vulnerabilities. These vulnerabilities can be understood to attempt to recognize certain geographic areas that may need more or less assistance than others during times of crisis. Adding to this, knowing the populations sentiment towards a variety of topics can assist in response efforts. If a manager can gauge how a population feels about their response efforts, quick judgments may be able to be made about how those effective those response efforts are.

Wrapping up the considerations for the information needs categories is incident identification. Similar to the ability to identify damage is being able to identify potential crisis/disaster incidents as they occur. Much like how the sooner specific damage is identified the sooner it can be rectified, the sooner the whole crisis event is identified the quicker response efforts can be organized. Providing potential incident or event detection services gives emergency managers another information avenue to identify events they need to respond to.

Recovery

For the recovery stage, social media should again be utilized to gather information. The type of information changes though from the needs during the response stage. The shift comes from the goals of the stage. Response is focused on providing immediate assistance to those who need it why recovery is focused on returning the impacted areas to their prior states

From the interviews comes some specific uses of social media during the recovery phase of emergency management. Included in these uses are more traditional public affair activities,

two way communication with the affected populations, and monitoring for continuing impact from the original event. The first two of these uses shouldn't require the use of any data analysis tool, as they are activities that have been completed since the advent of emergency management processes. Emergency managers already have the tools they need to publish information to the public, and can use existing functions in social media platforms to communicate back and forth with the public if desired. Similar to monitoring for the information needed during response, social media has the potential to be used to monitor for information relevant to the recovery stage. Building on the thought of monitoring for continued impact, social media analysis being utilized for recovery needs to be able to identify how well the response efforts reacted to and solved the problems caused by the crisis/disaster event.

Focus on Reporting Needs

Not only to properly examine information obtained from social media but also to provide end results to various stakeholders, social media analysis tools should have various reporting functions. These functions should be created based on what information is being reported or presented and who the information is being provided to. Various methods of presentation were identified during the coding process including GIS integration, graphical representation of data, categorical description of data, and paper reports indicating priority information.

These different methods each have potential to be useful in the presentation of social media data analysis, as long as the right person is being provided the right method. A simple example of this would be to consider providing a tool to a GIS analyst. As implied by their title, they would be working with GIS tools during crisis response activities. If hoping to aid them in their work by providing data analysis of social media, the focus of the tool should be on social media integration with GIS platforms. At a higher level, if seeking to build an analysis tool to

provide information to a decision maker, the end analysis product could consist of a list of priorities that should be considered. Examples of these priorities could be a list of locations that have suffered damage, a list of common complaints from the impacted population, or a list of resources needed by different vulnerable groups amongst the impacted population.

Chapter 6

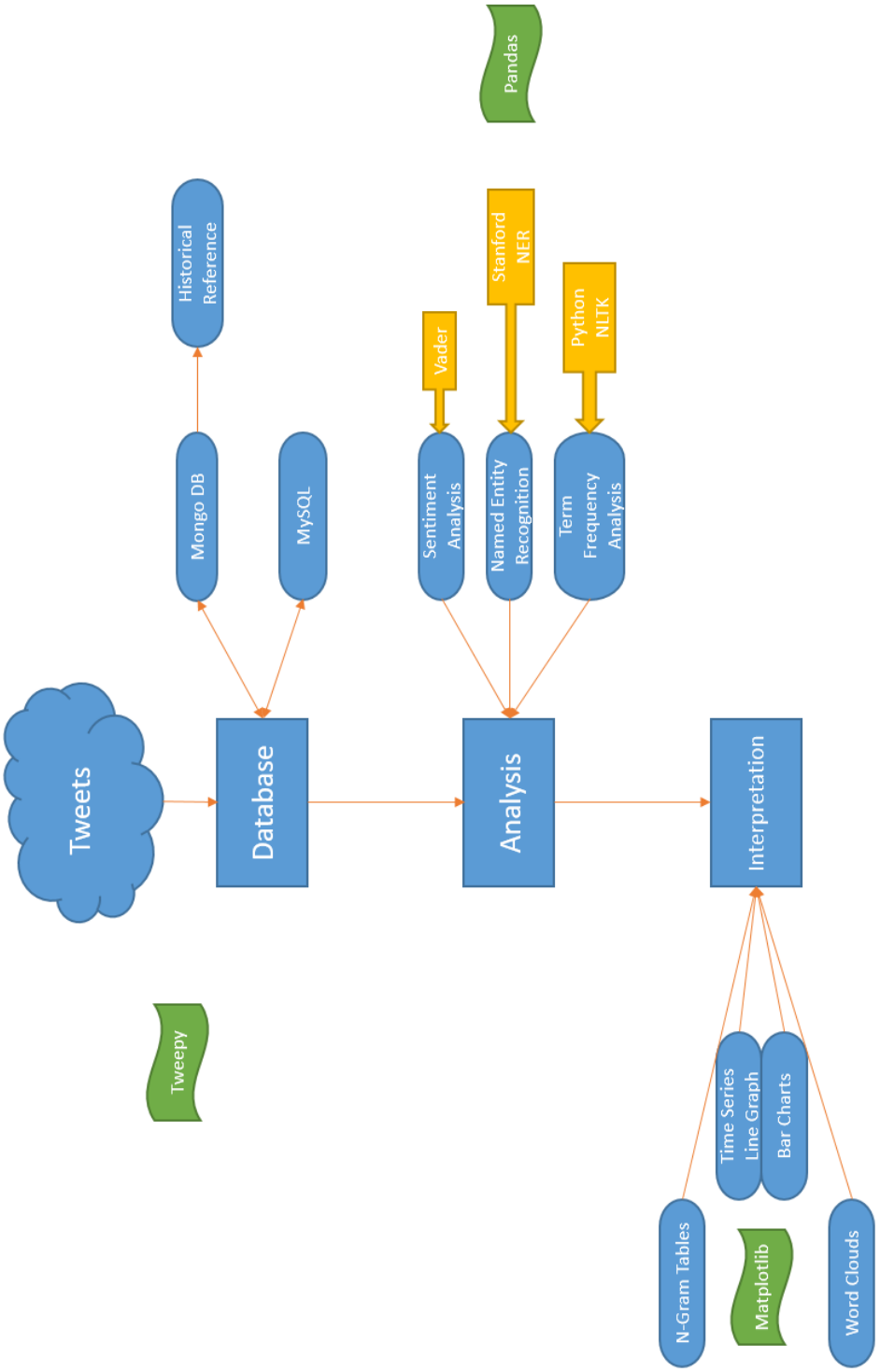
Prototype Development

Alongside the semi-structured interview study, a few different analysis tools were prototyped that take and examine social media data. These tools utilized the natural language processing methods discussed in Chapter 4. They provided a number of analysis samples that were used during the interview process to show the participants some potential uses of social media data. They also assisted in providing development experience so that when design considerations were being created there was background work to build upon.

As indicated in the methods section, a few different NLP methods were used in the creation of these prototype analysis tools. Although each method provides different types of information, each method followed a similar creation and data flow process. In short, the data flow process used followed these steps. First, a data source was identified, in all cases the Twitter platform was used due to its openly available API and the existence of easy to learn tools that aided in the use of its API. Second, data was targeted and collected from Twitter and stored in SQL and Mongo databases. Third, this data was then processed to be used by existing NLP tools. Analysis was then performed on the processed data, utilizing different NLP methods. Lastly, the results of the analysis methods were visualized so that they could be interpreted.

Figure 20 illustrates the overall process used, laying out the different steps and tools involved in conducting analysis of social media data. Included in the figure are different steps, platforms, and tools that are used throughout the process. Tweets were captured from Twitters API using the Tweepy python package and placed in databases. Then Pandas was used to format the contents of the Tweets so that they could be analyzed by different NLP tools, a sentiment analyzer, a named entity recognizer, and a term frequency analyzer. Following this analysis, Matplotlib was used to create visualizations that could be interpreted.

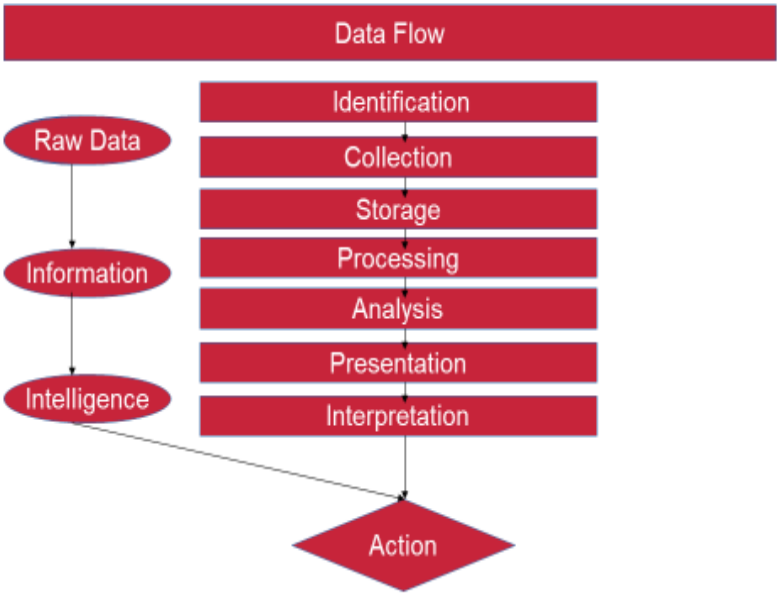
Figure 20: Data Flow with Tools Used



Data Flow

To facilitate the use of social media data for disaster response activities, there needs to be a way to transform the raw social media data into actionable intelligence. For the sake of this discussion raw data will be considered to be Tweets that are created during some disaster situation. It is important to note though that the concepts discussed here are not limited to data collected from Twitter. There exists the possibility to use similar data flow processes on data collected from other social media/internet sources. Actionable intelligence will be considered the end product of taking those Tweets and running them through this proposed data flow process. This matches with the description Dupont, 2003 gives which was discussed in the literature review. This process, briefly outlined in Figure 21, has been created to provide a list of steps to consider following when creating analysis tools for social media data.

Figure 21: Data Flow Process



Each step in this data flow process plays a role in the process of creating actionable intelligence. As the process progresses, a more complete intelligence product is created. The process starts with steps concerned with identifying and collecting data. The data identified should be relevant to whatever situation or event those using the process are interested in. The middle steps focus on taking that data and preparing it for the analysis tools. At this point information about the event is being formed based on the utilization of the collected data. Ending the process, is the analysis of the data, its presentation, and interpretation. This is where intelligence is created. At this point, decision makers have been given access to actionable intelligence that can be included in their decision-making processes.

Following are descriptions of each step presented in Figure 21. Each step comes with its own requirements to be completed, whether they be personnel to carry them out or software/hardware tools to perform computational tasks.

Data Identification

Arguably one of the most important steps, data identification, is where the data flow process begins. This importance is derived from the fact that if non relevant data is targeted for collection, then no matter how much analysis is conducted it may never become useful. The success of this step falls upon the personnel using a tool or platform that is making use this data flow process. These personnel are also those that are responsible for deciding that there is a need for data identification. The users should be subject matter experts that are aware of what information they require to carry out their operations. By allowing the users to focus the tool towards the topics that they believe are important, the tool will be able to leverage their expertise. Hence, the focus of this step is to determine what information is required to aid in response efforts.

Part of data identification is understanding what platforms exist that can produce the data you are looking for. Throughout this research the data being identified has come from social media content. Twitter, now known as “X”, was the primary platform targeted. This was due to the ease of access to its API, its real time nature of content creation, and its popularity. Other platforms that have been considered for use include Facebook, Instagram, Snapchat, and more traditional news organizations. Any data source that’s on the internet has the potential to be targeted for data identification as long as the content being produced is relevant to the event of interest. The more often and more current the content the better.

The Test Cases section will elaborate further but for the sample analysis done as part of this research data has been identified based on news reports of active natural and man-made disasters, and the use of generic key words related to the State College, PA area and The Pennsylvania State University. The disasters include the invasion of Ukraine by Russia, and a hurricane event. This identification also represents two different potentials times at which this step can occur. As it is the first step, it generally will take place before or in the beginning of a crisis/disaster event. Data identification based upon news reports could be considered a reactive identification, as the efforts are being done as a reaction to the event. The use of generic key words could be considered a proactive attempt at identification. Identifying the existence of data related to State College, PA and then collecting/analyzing it could lead to changes in the analysis being noticed over time. These changes could be indicative of a real word event that needs to be responded to.

Data Collection

Following the identification of data that will be used as part of a disaster event response is the collection of the data. This collection effort will look different depending on the specific social media data source.

There are a number of ways to access Twitter data, but the method used has been a python script that accesses Twitter's API. Once the API is accessed, a list of keywords is used to obtain tweets that contain said keywords. These keywords should be created to target data identified in the data identification step. Again, this becomes part of the job of the personnel utilized whatever tool was created that is following this process. These keywords become the basis for the rest of the data flow process so they need to be able to identify data that will be able to become useful for those who need it.

To perform this step the python tool Tweepy is being used (*Tweepy*, n.d). This tool provides syntax in order to connect to and query the Twitter API. These queries then collect data from the API which can then be provided to other python functions.

Data Storage

Once the tweets have been identified and collected from the API, they need to be stored in some way for use. Currently, two databases are being used - MySQL database and a MongoDB. Both provide the ability to query and access the data, but the data is placed into each database slightly differently. The MySQL database needs the specific attributes present in the Tweet to be clarified for data to be stored. This requires the database to be set up ahead of time with columns for each attribute. The MongoDB is able to take the whole tweet and store it in the database with no set up required. Storing the whole Tweet allows the option to examine attributes in the future that were not thought of at the time of collection.

Storing the data allows for it to be queried by the processing and analysis tools both in real time and in the future. Having the ability to examine past data allows for comparisons to be made between events currently happening and those that have occurred in the past. These comparisons can assist in building an understanding of how any given event may be similar to a past one aiding in decision making.

Data Processing

In order to perform any analysis, the data needs to be structured in such a way that it is able to be parsed by the analysis tools. To do so, the Pandas python package is used to organize the data from the Tweets into "data-frames". With this data-frame, the data can then be preprocessed as necessary for each analysis process. This could include punctuation removal, tokenization, and stop-word removal. Preprocessing functions assist in the analysis tool's ability to quickly parse data. Removing text that isn't necessary for the analysis tool's ability to perform its functions streamlines the whole process and aids in the completion of the analysis.

Data Analysis

Initiating the transition of data to information is the data analysis step. Here is where the bulk of computation will take place. This computation is being done with the goal of making sense of the raw text data that has been identified, collected, stored and processed. In order to make actionable decisions, the decision makers need to have information that they can interpret to create intelligence. To create this interpretable information, this data flow process utilizes a few different Natural Language Processing methods. These methods include Sentiment Analysis, Named Entity Recognition, and Text Frequency analysis. Each of these methods provides different information about the data that has been collected. Additionally, they provide examples of what can be done with social media data

Sentiment analysis has been use to elicit information related to the emotions present in the collected text data. Named Entity Recognition attempts to identify various "entities" that exist in text. These entities include names, user handles, organizations, locations, et cetera. Text frequency has taken the form of n-gram generation and word cloud creation. To perform these

three analysis tasks the existing tools VADER, Stanford NER, and pythons NLTK have each been used respectively (Hutto & Gilbert, 2014; Finkel, 2005; Bird, 2009).

These tools allow for both static and real-time analysis. For the static analysis, a selection of the stored data is queried and then provided to one or all of the aforementioned tools. The real time analysis would provide collected data to the analysis tool in set intervals as data was being collected. As an example, when running a real time sentiment analysis VADER would be provided the most recent minute (or any desired time period) of data collected to be analyzed. Its output would then be send to a visualization tool which is also updating every minute with the new analyzed data.

Data Presentation

No matter how accurate the results from the data analysis might be, if they are presented in an ineffective manner, they become useless. This data flow process uses a few different forms of data visualization. These include graphs, tables, and word clouds. Also, it is important to note that the graphs and word clouds have been presented both as static and real time. The updating visualizations change as new data is provided to the visualization tools. To create these visualizations the python package Matplotlib has been utilized (Hunter, 2007).

This step ends the information creation portion of the data flow process. Having visualized the raw data, information about the identified data is now available and facts about the data can be discerned. The next and final step should take this information and transform it into intelligence that can be used to make actionable decisions.

Data Interpretation

The final step of this process is interpreting the results from the data analysis. This is where information is transformed into intelligence. This interpretation falls on those whose role it

is to either make decisions during a crisis/disaster or provide those who make decisions with the resources they need to make them. Interpretation can take many different forms and will also depend on the individual doing the interpreting. It should generally take the form of the interpreter deciding what the information is saying and what needs to be done in response to the information provided. Following this interpretation action based on the final intelligence created can be taken. Again, this action will take many different forms based on the situation at hand.

Test Cases

Making use of the data flow process are three different test cases. Each one of these cases takes a Twitter dataset that was collected in real time and performs several analysis tasks on them. These data collection and analysis efforts were conducted with the goals of providing samples of what social media data can be used for to provide during the interview study; and to see how existing analysis tools could be used to identify different information needs discovered through the interview study.

The included test cases were done using three different data-sets. First, a data-set collected focusing on State College, PA and The Pennsylvania State University. Second, a data-set collected looking for Twitter data related to Ukraine. Third, data collected relevant to Hurricane Ian, which impacted the state of Florida. Similar analyses were conducted on each dataset with various types of information being discovered.

Penn State Football

The first of the test cases was carried out on data collected during the summer of 2021. The dataset is made up of Twitter data that was collected using the search terms “Penn State” and

"State College". Originally, this search was being performed to test data collection abilities and some basic analysis tools. Included in these basic analysis tasks are sentiment analysis, n-gram recognition, and word cloud creation.

While the dataset was being collected, word clouds were being created in real time that visualized the text of captured Tweets. By happenstance, it was noticed that there was a sudden change of topic in the text appearing in these word clouds. Normally, there wasn't a lot of text appearing that seemed directly related to the State College, PA area or the Pennsylvania State University. It generally seemed as if there was enough other content being posted that included the term "State College" that drowned out any information related to the University and the town it is in. During this change of topic, terms directly related to the University, began to appear. A news search was done and it was found that around 18:00 UTC Penn State had made an announcement that Beaver Stadium would operate at full capacity for the 2021 football season. This was coming off of a partial capacity season due to the COVID 19 Pandemic.

After realizing that there was this topic change that was potentially driven by the mentioned announcement, the stored data was examined in three ways to try to better identify this change. Twelve static word clouds were created that each showed ten minutes of Twitter data that ranged two hours around the time Penn State made their announcement. N-grams were created for the ten minutes before and the ten minutes after the announcement. And daily sentiment scores were created for the previous and following weeks of data.

Looking at the static word clouds, a shift in conversation can be seen between the ones created before the announcement and the ones created after. Four of these word clouds are shown in this section, two before the announcement and two after.

Figure 22 and Figure 23 show the time periods before the announcement. In both of these word clouds there is no indication in the text that The Pennsylvania State University is being disused. In the first of the two figures you can see the terms "State" and "College" but there are

no other terms that indicate that these are referring to the town State College, PA which was one of the subjects of interest when creating these word clouds.

Figure 22: Word Cloud from June 1st 2021, 17:40-17:49 UTC

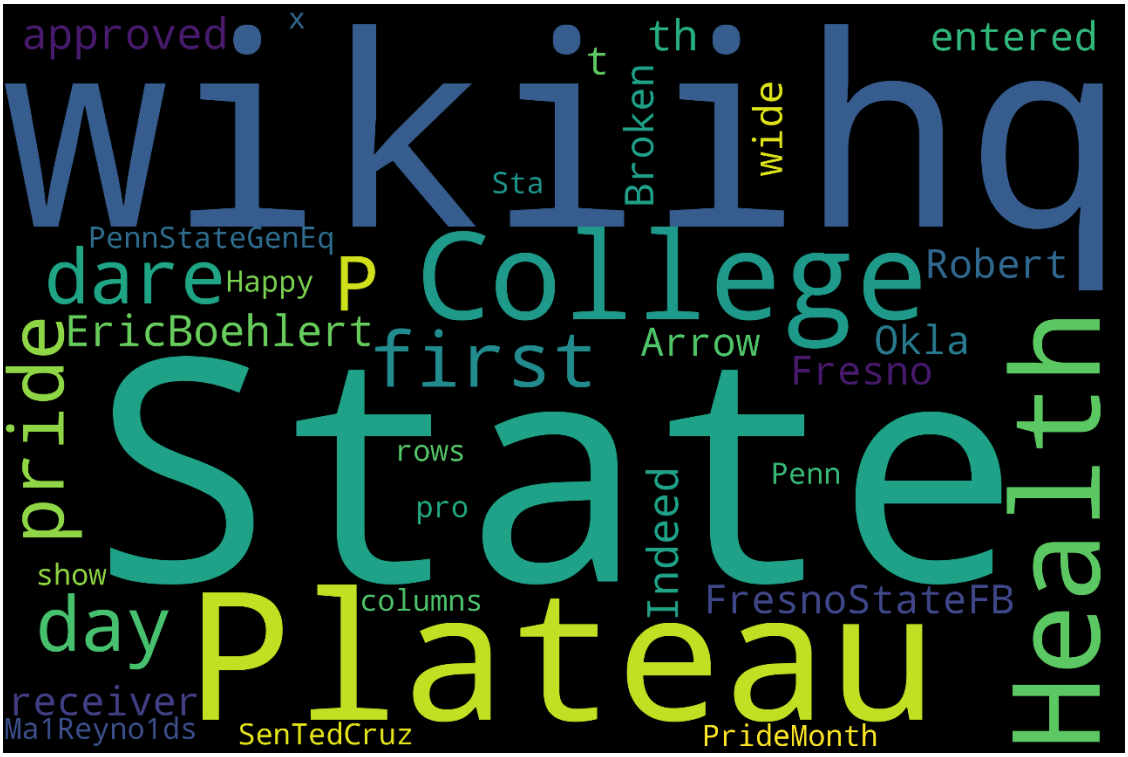


Figure 23: Word Cloud from June 1st 2021, 17:50-17:59 UTC

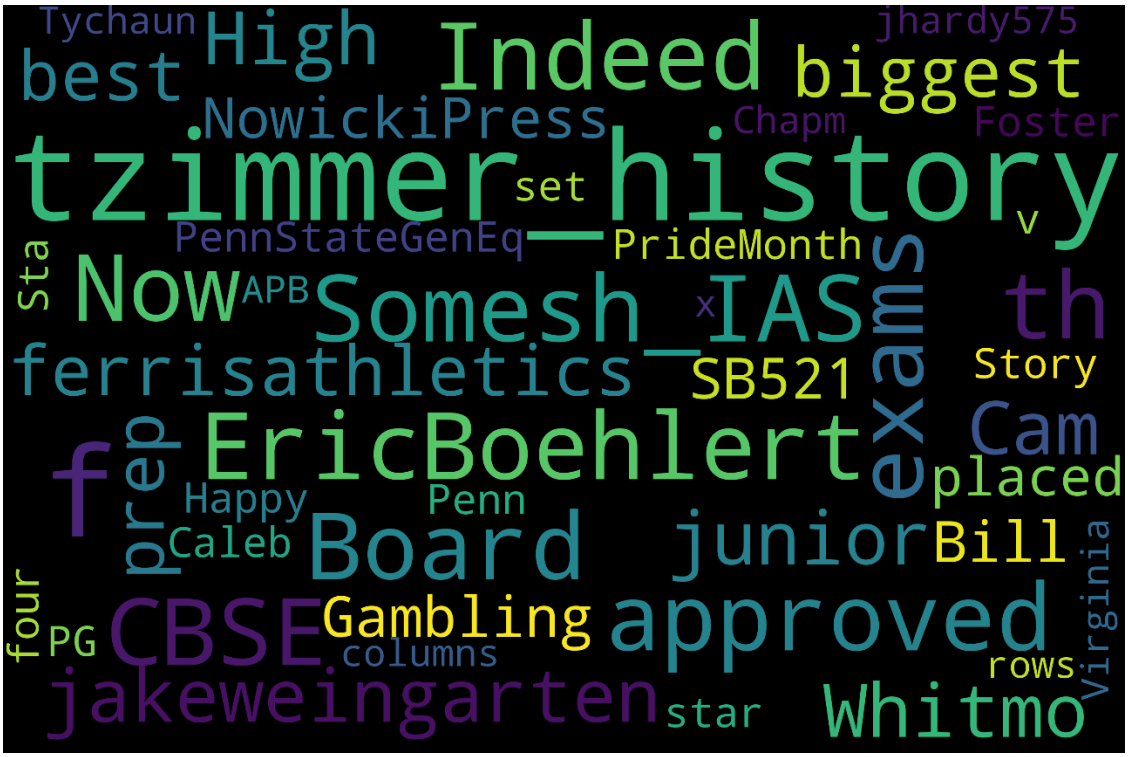


Figure 24 and Figure 25 show the time periods after the announcement. In these word clouds more text appears that is related to Penn State and State College, PA. In the first of these figures, “Penn” and “State” appear indicating collected content related to the University. Additionally the terms “announces” and “breaking” appear which indicated the potential for some sort of news broadcast. Furthering the terms appearing in the word cloud that indicate a topic change are “kickoff” and “sports”. The second figure continues the topic change with terms appearing such as “Beaver”, “Stadium”, and “capacity”. These show that the subject of conversation in the collected Tweets has switched to content discussing Penn State’s football stadium “Beaver Stadium”.

Figure 24: Word Cloud from June 1st 2021, 18:00-18:09 UTC

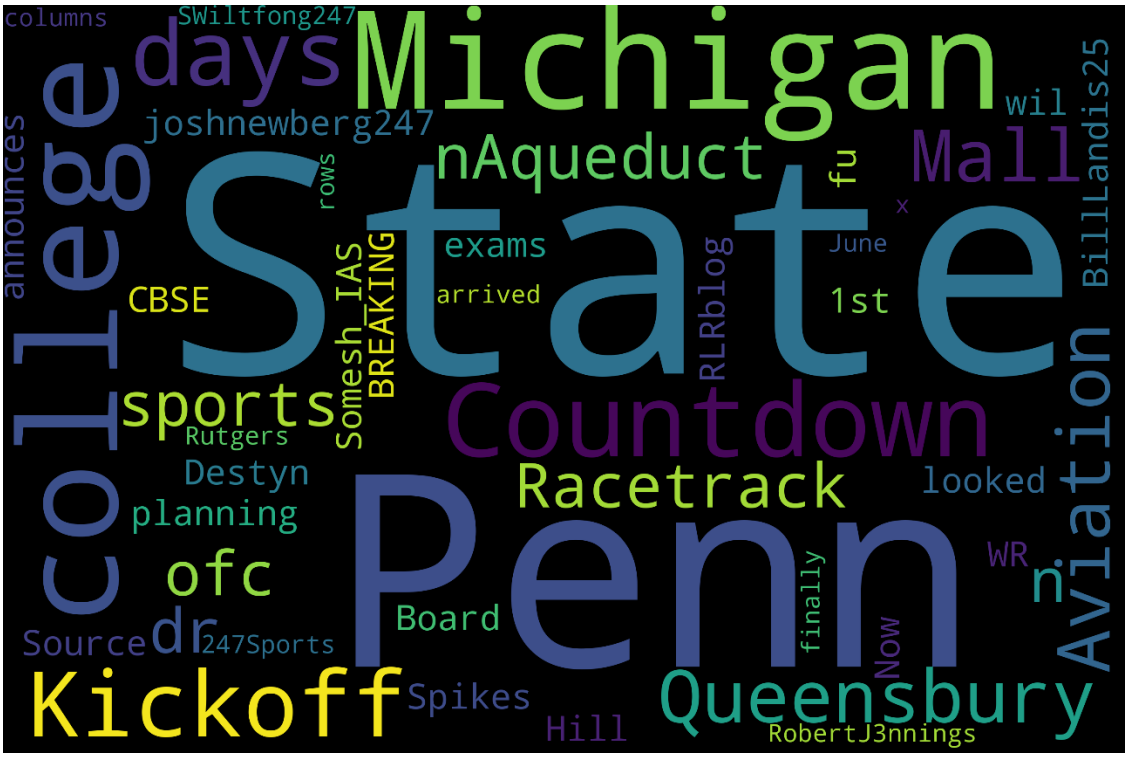
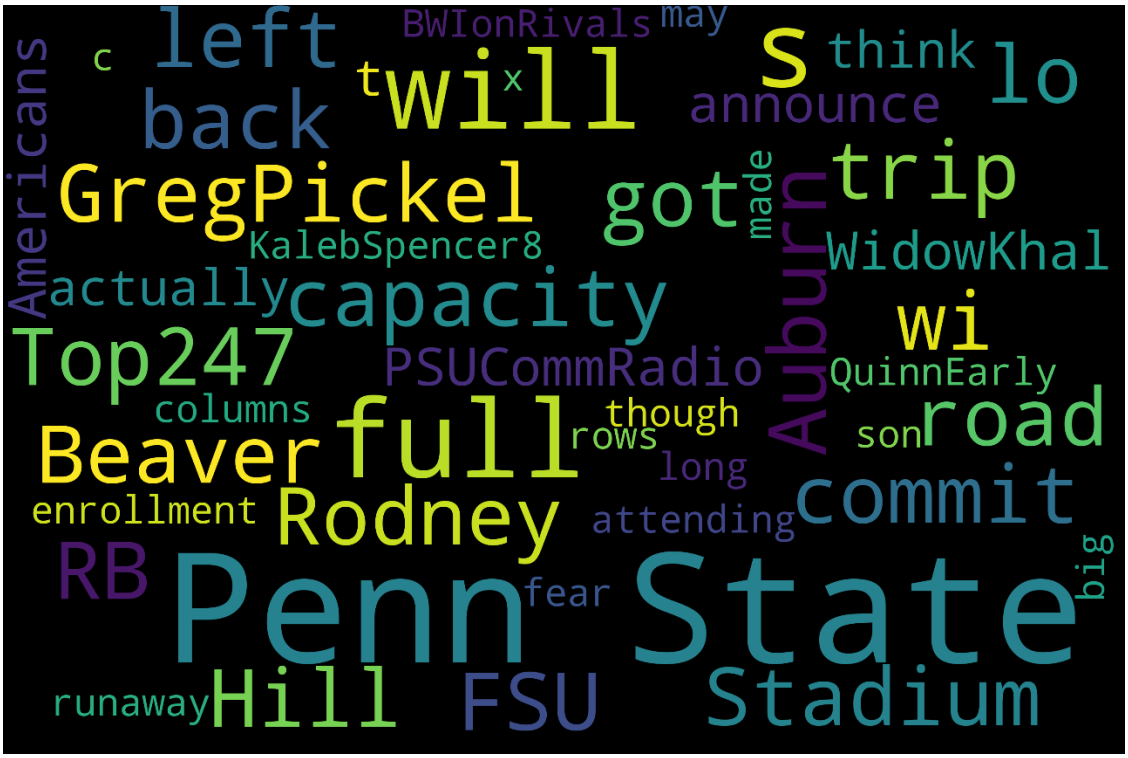


Figure 25: Word Cloud from June 1st 2021, 18:10-18:19 UTC



Adding to the word clouds was the generation of N-Grams. These word groupings also indicate a shift in conversation before and after 18:00 on June 1st 2021. The top five most common word pairings were identified and are shown in Table 25.

Table 25: N-Grams from June 1st 2021, 17:50-1809 UTC

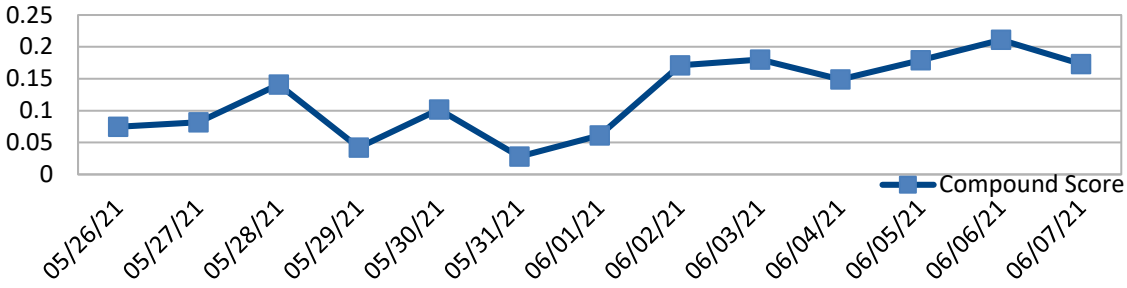
N-gram – June 01 17:50-17:59 UTC (N=5)	
N-Gram	Frequency
university, shift, equitable, aptitude, te	9
exam, cancelled, good, opportunity, university	9
rt, somesh_ias, cbse, board, exam	9
cancelled, good, opportunity, university, shift	9
cbse, board, exam, cancelled, good	9
N-Gram – June 01 18:00-18:09 UTC (N=5)	
N-Gram	Frequency
fill, beaver, stadium, full, capacity	24
state, officially, bring, fan, back	24
bring, fan, back, fill, beaver	24
back, fill, beaver, stadium, full	24
fan, back, fill, beaver, stadium	24

As with the word clouds these N-Grams show a difference of conversation before and after Penn State's announcement concerning the capacity of Beaver Stadium for the 2021 football season. Before the announcement, no terms are particularly related to the University. Afterwards, there appears to be discussion of Beaver Stadium and its capacity. Additionally, the frequency of each N-gram increased indicating that more Tweets were being captured, and therefore created.

The third piece of analysis done while examining this set of data was the creation of sentiment scores. These scores were created using the described VADER tool. Each data point in Figure 26 represents the daily compound score of all of Tweets collected and processed through VADER. All scores fell above zero with most falling above 0.05 indicating them as "positive sentiment." After the announcement made by Penn State on June 1st, the scores increased above

the previous weeks. This shows a possible change in emotion that went along with the change in topic indicated by the word clouds and the n-grams.

Figure 26: Daily VADER Sentiment Scores



This sample of data collection and analysis provides an example of how social media data might be used as a way to identify potential incidents for emergency managers. As described in Chapter 5, one of the information need categories is Incident ID. Emergency managers and responders need to be aware of the incidents that require their assistance and the ability to identify a said incident through social media adds to their capabilities. Being able to provide a system that detects topic changes in social media is a potential way to add to their response capabilities by giving them an extra tool in addition to the traditional PSAP system.

Ukraine

More serious than a football stadiums capacity limits, is the Russian invasion of Ukraine in February of 2022 (BBC, 2022). Like all military conflicts much traditional and social media content has been generated discussing the events. This provided a somber opportunity to collect data related to a real word crisis event to test potential analysis tools.

After this identification was the need to begin data collection efforts. "Ukraine" was selected as the search keyword. This decision was made in the effort to collect as many Tweets related to the country as possible to ensure a large dataset. Data collection began on the 23rd of June 2022 and ran through till the 29th of July. By the end of this effort there were 13,206,750 Tweets collected.

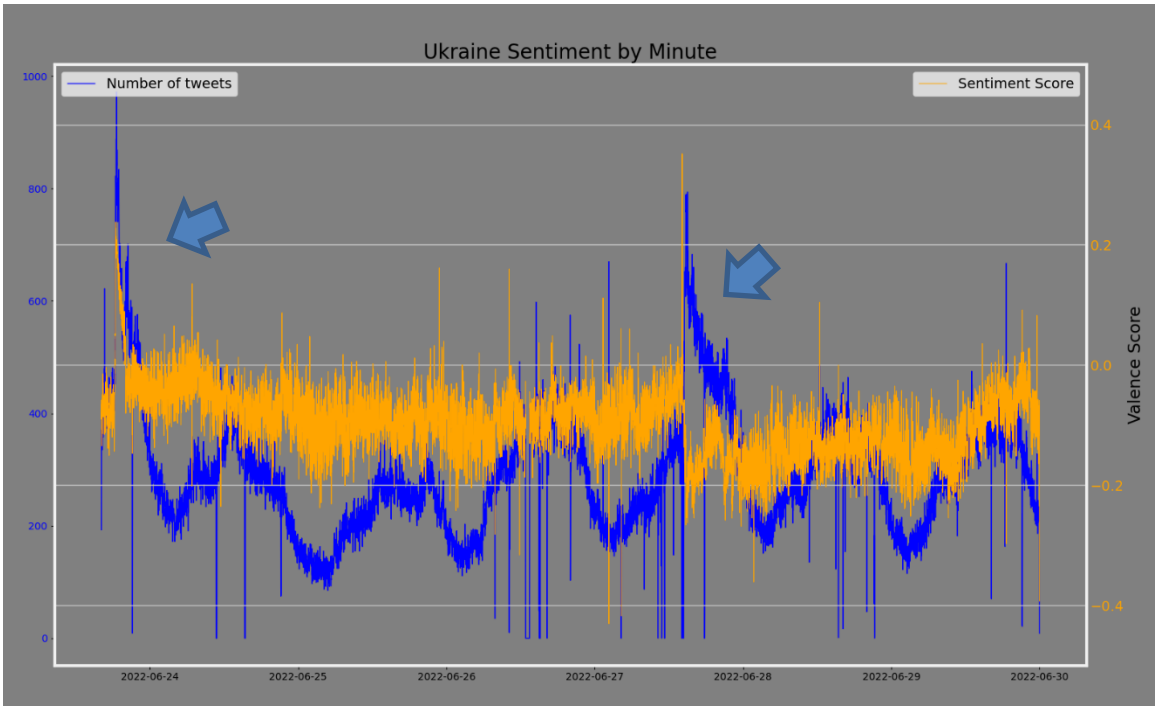
While data was being collected by Tweepy, it needed to be stored as Tweepy does not do this innately. The collected Tweets were placed in both a MongoDB and a MySQL database. This fulfilled the storage step of the data flow process.

In order to format the Tweets, which now existed in databases, the Pandas Python package was utilized (McKinney, 2010). This package was able to take data from the MySQL database using SQL queries and format the Tweets into dataframes which is one way Pandas organizes data. These dataframes would then be able to be used to examine the data with different analysis tools.

The analysis step of the data flow process for this test case utilized both real time and static analysis methods. While data was being collected, sentiment analysis, named entity recognition, and term frequency analysis tools were being utilized to learn about the collected data. The time variables used during the real time analysis varied as data was being collected to see the different outputs. The tools used to do this analysis were the previously mentioned VADER, Stanford NER, and the Python NLTK. These tools provided different ways of examining the data once the results of the analysis had been visualized. Figure 27 shows approximately six days of the Ukraine data-set. The data was resampled by minute and, as mentioned, VADER was used to create sentiment scores for each minute of data, indicated by the orange line. These scores were created by averaging the sentiment of each individual Tweet that had been collected in each minute of data. The blue line shows a count of Tweets per minute.

This specific graph was generated statically, rather than being created in real time as data was coming in.

Figure 27: Ukraine Sentiment Analysis



The creation of this graph fufilled the data presentation step of the data flow process. To generate it, the python package matplotlib was used (Hunter, 2007). Also created with matplot lib were word clouds and bar charts. Although this one graph was staticly generated, the majority of visualizations created to present that data were done in real time. A time series graph similar to Figure 27 was updated with new data as it was collected, an updating word cloud was produced that worked as the one descibed in the previous section did, and bar charts showing the most commenly identfied entitiys were also updating in consistant time intervals.

Following the creation of the different visualizaions was the intepretation of the data that had been presented. When the graph shown in Figure 27 was created two points of interest emerged, one at the beginning of the Time-Series, and one towards the middle. The first point of

interest is an increase in positive. Also occurring with this increase of positive sentiment is an increase in number of Tweets captured. The second point of interest is an increase of negative sentiment. Again, there was also an increase in number of Tweets captured. Additionally, this increase of negative sentiment seemed to stay more consistent over time than that increase in positive sentiment had.

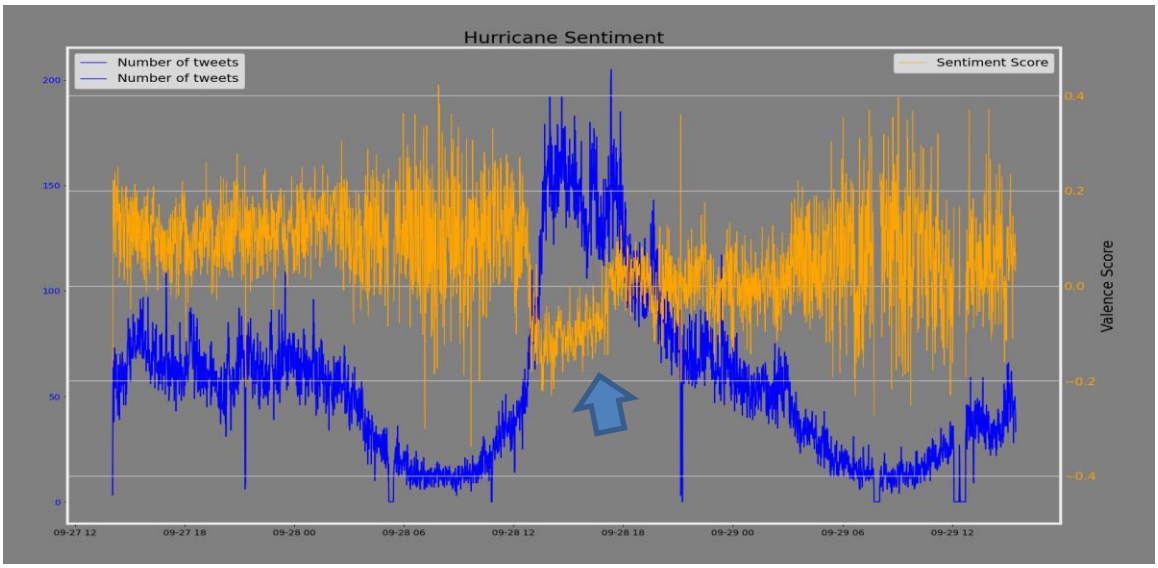
After noticing these two points of interest, it was assumed that something must have occurred to cause this change in sentiment and quantity of Tweets. To investigate this assumption a news search was performed. Two items of note were found. First, correlating with the first point of interest, were reports that the country of Ukraine had been accepted as a candidate member into the European Union (Parker et al., 2022). The second point of interest correlated with reports that Russia had carried out a military attack against a Ukrainian shopping mall (Wertheimer, 2022).

Thinking through this anecdotal correlation between changes in sentiment of Tweets and real word actions of world governments, an argument exists that the process explained here may exist as a rudimentary event detection tool. Having the ability to constantly examine data related to a topic of interest and have that data reflect events occurring offline has the potential of providing valuable information to those in emergency management.

Hurricanes

Adding to the test cases are data-sets collected regarding various Hurricanes that formed off the coast of Florida, later impacting the state causing widespread damage. Specifically, Hurricane Ian from 2022 and the areas in Florida that it impacted were targeted. The visualization seen in Figure 28 was created in the same manner as the Ukraine example.

Figure 28: Hurricane Ian Sentiment



Similar to the last test case, a point of interest in the sentiment scores and number of tweets was noticed. This decrease in sentiment and increase in Twitter traffic roughly aligned with the landfall of Hurricane Ian. Although this potential identification of a hurricanes landfall wouldn't provide much value to meteorologists tracking it, it does show that there likely is a match between real word events and the conversations concerning them on social media. This understanding has the potential to be generalized to other data-sets. If the data flow process is being run in real time on a data set that is known to be consistent, any changes in the output of the analysis may be indicative of a real word event that needs to be examined.

Validation Attempts

While creating NLP tools that were examining different social media datasets, attempts at statistical validation were made. These validation attempts were done on time series data of sentiment scores of collected Twitter data. Two different methods were tested including the use of ARIMA models and the creation of running standard deviations. The goals of both methods

were to build a “status quo” state of social media where data was being examined when there was nothing interesting occurring. Then, as time passed and more data would be collected the new data could be compared to the “status quo” state and changes could be identified. The hope here would be that these changes would be indicators of real word events that warranted the attention of whoever was utilizing the social media analysis tool.

In the case of the ARIMA models, which is a predication model for time series data, a set of historical data would be provided to the model which would be used to create a prediction for future data. After this prediction was created, current data being collected in real time could be compared against it to see if it matched with the prediction. If there was a match it could be assumed that nothing has changed in the social media space. If there is significant variation then there is the possibility that a real word event has occurred that is influencing the data on social media. This event can then be identified and researched to see if there is a need for further monitoring by the emergency managers.

The second method, running standard deviations, operates with similar goals just in a slightly different manner. Attempts were made to calculate the standard deviation of time series data to again build a “status quo” state. Once this state was established, new data coming in could be compared to the running standard deviation. If new data fell outside of the calculated standard deviation then that could be an indication that a real word event caused a change in social media data and that event could be possibility important for an emergency manager to be aware of.

Chapter 7

Findings and Contributions

Circling back to the original research goals and questions of this dissertation, Chapter 7 provides an overview of the results of this work. Having completed the research studies, this chapters is able to propose and discuss answers to the research questions and present a few different contributions to the Crisis Informatics field. The proposed answers to the research questions come from the knowledge that has been gained from both the semi-structured interview study and the creation of prototype tools and their use in test cases.

From the combined findings of the research conducted for this dissertation, are three different contributions to the Crisis Informatics field. In short, these contributions are the design considerations presented at the end of Chapter 5, the Data Flow process proposed in Chapter 6, and the beginnings of a method of Event Detection that comes from the analysis results of Chapter 6. These contributions have provided stepping off points for future research in the Crisis Informatics field, specifically with social media usage during crisis response.

As stated in the Introduction, the work sought to take a step back from the direct analysis of social media data, and ask questions about the desires of those who are seeking to make use of social media data. At the end of this research process it appears that a viewpoint on how social media data should be used has been discovered. This viewpoint can be able to be used to influence the development of social media analysis tools for use during crisis responses. Additionally, it has been shown that social media data can be collected, processed, analyzed, and interpreted to provide potential intelligence about real word events that are occurring.

This chapter will continue with two sections. First, is the answering of the six research questions that were asked at the beginning of this work. Second, are the research contributions

that this work claims to have made? Along with these contributions, is a discussion on some additional fields that the findings of this research could be potentially applied to?

Research Question Answers

Utilizing the results of the coding processes completed as part of the semi-structured interview study presented in Chapter 5 and the interpretations of the test cases presented in Chapter 6; answers are proposed for the research questions that were asked at the end of Chapter 3. These questions were originally generated to produce research that would aid in the creation of social media analysis tools and platforms for use during crisis response efforts. The hope being to fill gaps in the Crisis Informatics field related to the practical use of such tools. The proposed answers for research questions one through three primarily come from the descriptive analysis and design considerations produced by the Semi-Structured Interviews of Emergency Management Professionals study presented in Chapter 5. The answer for the last research question was primarily influenced by the prototype tools and test cases discussed in Chapter 6.

RQ1: Is there a desire/need for a social media analysis tool?

Yes, a need exists for social media analysis tools. This need has been identified through the examination of the information categories created from the interview process. In order to provide the information requesting from these categories, thorough examination of social media needs to be completed. This examination requires more processing and analysis than what can be done utilizing social media platforms as they exist. This need leads to the justification of spending time building an understanding of what these tools should provide to those who wish to use them. Additionally, if tools to perform this sort of analysis existed in a form that emergency managers could easily make use of them it would have been expected to be told about them by the

participants. This never specifically came up in the interviews and none of the participants discussed any specific tool they had to utilize social media data in their operations.

Additionally, certain interview participants specified the need for a new tool or the lack of one currently existing. Participant 4, who works for a state level emergency management organization, states:

> *…I've been looking at a number of different tools and so far I haven't found anything that gets everything and yet can still make it a manageable amount of information you can drink from the fire hose.*

This statement helps support the need for new/more social media analysis tool development. Emergency managers at state levels are actively looking for platforms to use for social media analysis and have yet to find one that performs in the way they need it to.

RQ2: How are emergency managers currently using social media?

Emergency managers are primarily using social media as an information pushing tool. They utilize different social media platforms to push preparedness information to the public, notify the public about ongoing incidents, spread weather information, etc…. Alongside this primary use is some light observation of social media. This observation is mostly done by just using social media platforms as they are intended to be used, causally looking for conversations that may indicate something of interest is occurring.

The motivation for their current use has been driven by a few different factors. Some of the participants had specific events occur that led to a response on social media that began interest and others gradually adopted the use of social media as social media platforms became more popular. Included in the specific events are an Amtrak train derailment that the participant learned about from social media before being officially notified and social media posts about the plane that landed in the Hudson River.

RQ3: When does an accurate and timely social media dataset become useful for emergency management operations?

An accurate and timely social media dataset has a place in emergency management operations throughout the emergency management process. Its use is most prevalently desired in the preparation, response, and recovery phases, which each phase having its own requirements. Table 21: Emergency Management Stages Category Counts and its attached section discuss these phases and the Chapter 5 section "Focus on the Stage" builds upon social media usage during each phase as part of the proposed Design Considerations.

There were no indications that social media data would be more or less useful for any one specific type of crisis or disaster event. This is seen through the prototype development process. Data was able to be found, analyzed, and interpreted in three different areas; the benign announcements related to football stadium capacities, identification of a hurricanes landfall, and the identification of various wartime activities.

A caveat on this answer is the assumption that the types of events being considered for social media analysis are those that are appropriate for emergency managers to examine. Disaster/crisis events exist that would not necessarily be appropriate for social media analysis, but these types' events also would not necessarily require an emergency manager's attention. Something like a small vehicle accident may exist as a crisis event to those involved, but it can be expected that the impact of that accident will not require much in the way of information gathering. What seems to be an indicator of social media's usefulness is the amount of time that is required to respond to an event. The longer a crisis goes on for the more resources are needed to respond to and tackle the challenges being presented. During this time period more data is also being generated on social media about the incident. These types of events that begin to take days to weeks to resolve have the potential of benefiting more from social media data that shorter term problems.

RQ4: When an appropriate event is identified, what types of analysis tools and processes need to be available for emergency managers to use?

When considering the types of social media analysis tools that should be made available to emergency managers no specific types of tools emerged. Rather, there was interest in obtaining different types of information. The information desired changed based on the emergency management phase currently being conducted. The types of information desired were shown in Chapter 5 in Table 9: Code Categories and Table 17: Information Needs Category Counts. The most common information need from this table was "damage information". This took the form of participants wanting information on topics such as what kind of damage exists, how many homes have been impacted, what kind of injuries exist, and how extensive any power outages may be. Obtaining this type of information requires the use of text processing and topic identification tools. Focusing tools towards the identification of "damage" related keywords may assist in the obtaining of this information need. Alongside this desire, was also the desire for photos of damage. Data mining different social media platforms for photos containing damage will also aid in providing emergency managers with information they desire.

Also important to consider are the communication directions emergency managers use and the existing information gaps. Although these are not types of tools, they provide insight into what tools could be used or created to meet different needs. Table 16: Communication Direction Category Counts, from Chapter 5, lays out the different communication directions used by emergency manager and its section gives description. Table 18: Information Gaps Category Counts does the same but for information that the participants claimed to be missing. Understanding the current methods by which emergency managers are using social media to communicate can better focus the development of analysis tools in two ways. First, one can assist in the ways emergency managers are already communicating. Providing them with more efficient tools and processes to perform the work they are already conducting can help introduce them to

the use of new types of technology. Second, one can provide opportunities to utilize communication directions and methods that the emergency manager may not have the current abilities or resources to use.

RQ5: What information should this social media analysis tool provide?

Social media analysis tools should provide a process for emergency managers to take raw data from various social media platforms and transform it into intelligence. Different specific categories of information have been found to focus this intelligence creation process and provide guidance for the type of data that should be targeted. These information desires range from wanting knowledge directly related to damage being caused by a crisis event to more abstract ideas such as knowledge of an area's population (vulnerabilities, demographics, etc…). The table below, Table 26, displays each one of the information needs categories that was identified.

Table 26: Information Needs Categories

Information Needs	Resources needed	Impacted population locations	Impacted population data	Damage information	Population Sentiment	Misinformation identification	Incident identification
Participant Count	4	3	3	6	3	5	2

Obtaining the information each one of these categories represents should be the driving motivation behind a social media analysis tool that is being designed to aid in the emergency management process. Through the semi-structured interview process these are the types of information that the participants indicated as being useful to them in their operations. If an analysis tool is not targeting information deemed to be useful, then it will be difficult to convince your audience that they need your platform.

The creation of these categories came from pulling out quotes from each participant related that helped answer each interview question and fell into one of the codes that were

created. The quotes were then examined to determine key take-aways. These take-aways were then examined and grouped together into the information needs categories displayed above. This process was followed for each interview question/code. Chapter five shows examples of responses that were used to create the categories.

RQ6: Who should the tool provide the information to and how should that information be presented?

Many different potential users of social media data have been identified through the interview process. The different in users seems to be based on both the size of the different emergency management organizations each participant belongs to and the organization processes each group currently use. Interestingly, none of the emergency managers interviewed held the opinion that social media should be provided to someone acting in a 911 dispatcher role or mentioned PSAP's. All positions mentioned when asked about who should utilize social media data were those involved in the emergency management process, specifically those who would work in an EOC. Included in the types of individuals who the participants believed should make use of social media data are those working in information/communication units of an EOC, individuals in charge of making decisions, specific social media units, GIS units, Planning units, and finally were participants who believed that the tool should be tailored to be used by anyone.

The primary presentation method identified from the participants was a desire to have the data integrated into existing GIS platforms. This would make the data easy to contextualize as the user would have the ability to visually identify where the data is coming from, and then examine what the data is telling them. However, the integration of social media data and GIS platforms leads to a new problem, which is the lack of location data in the metadata of various social media platforms. Alongside the desire for GIS integration, were desires for basic reporting functions, the creation of various graphs, and the presentation of categorical information.

Considering what has been learned from the completion of the Semi-Structured Interview study and the completion of the Prototype Tools, various NLP and data mining methods appear to have relevance when providing analysis tools to emergency managers. These methods range from those that assist with data collection, to those that interpret and quantify text data. Tools that have been used include Tweepy, MySQL, Pandas, VADER, StanfordNLP, Python's NLTK, and Matplotlib. Each of these tools has played a role in examining social media data and transforming it into intelligence that can be interpreted.

Tweepy has been successfully used to obtain social media data (Tweets) related to a number of different real world disaster situations including hurricanes, earthquakes, and armed conflicts. MySQL is then able to store the data collected in the collected Tweets for further use. Pandas formats the Twitter date in ways that analysis tools can then processes it. VADER, StanfordNLP, and Python's NLTK are then able to perform NLP tasks such as Sentiment analysis, Named Entity Recognition, and Term Frequency Identification to summarize the collected social media text data. Matplotlib is then able to visualize the results of the NLP tasks so that the information created from the data can be interpreted and used as intelligence.

Contributions

In the process of completing this research four primary pieces of new knowledge have been added to the crisis informatics field. First, is the compilation of transcripts and recordings from 11 interviews with 14 different participants. These transcripts can be examined by others for other interpretations to be made from the participants responses to the questions asked. Next, is the identification that emergency managers have a need for some sort of social media analysis tool. The current uses of social media by emergency managers rely on the manual examination of social media data which does not lend itself to use during crisis events. Following this, is the

identification of specific information needs that emergency managers have of any tool that examines social media. This identification gives tool developers a focus point to collect data from social media and then turn it into actionable intelligence to give to emergency managers. Finally, it has been shown that the use of different NLP methods can identify real word events from summarized data collected from Twitter. This gives credence to the use of social media as a data source during emergency management operations and acts as a starting point in filling one of the identified information needs, incident identification.

The first three of these claimed contributions that are adding knowledge to the crisis informatics field go hand in hand. The compilation of the transcripts in of itself provides a dataset that can be made available to other researchers who have similar questions concerning social media usage for crisis and disaster response. From the examination and interpretation of these transcripts, it has been identified that some form of social media analysis tools would be useful from emergency managers to have. Following this, descriptive analysis has been done on these transcripts and twelve different areas of information have been identified and categorized. These information areas provide information on the backgrounds of the participants, how they currently use social media, what types of information they would like to have from social media in the future, who the information should be provided to, and how that information should be presented. These information areas were discovered during the coding process of the transcripts and line up with the questions that were asked during the interview. In short, they are the answers to the interview questions found within the transcripts.

The information found within the transcripts can be examined to help understand how emergency managers are currently using social media and what they expect from tools that seek to utilize it as a data source. Anecdotally, those who work in the emergency services field are generally resistant to change, and taking on new ideas. There is a culture where they know what works and what doesn't and don't like to introduce lots of new process. Having succeeded in

gathering interview results from 14 different participants is a success in of its self. The general positivity from the participants towards the use of social media data can be used to help promote the concept to others in the field. If a social media analysis tool is built using input from these interviews, the fact that it was built with emergency managers input can be used to sell it to others in the field.

From the current experience information area, it was found that most of the participants use social media in an information pushing manner. They are primarily using social media to push preparedness and awareness information to the public. Those that do use social media in an information gather context, have appeared to do so in a traditional monitoring fashion. In order to truly obtain the information they expressed as being interested in having in the information desire area, manually monitoring social media would be incredibly difficult. This leads to the idea that some tool is required to be able to streamline the information gathering process.

Included in these information areas are participant background, experience, platform use, motivation, potential interest, communication direction, operation scale, information desires, information gaps, presentation needs, social media users, and social media stage. Each one of these areas has been further broken down, with different categories of responses that make up each area. These categories have been shown and explained in Chapter Five as part of the semi-structured interview coding process. To elaborate here, the information desire category is one that has direct impact in what a social media analysis tool should be attempting to discover from social media data. The categories of responses found in this area include Resources needed, Impacted population location, Impacted population data, Damage information, Population sentiment, Misinformation identification, and Incident identification. Each one of these categories provides an opportunity for data targeting and data analysis. For example, if a tool is seeking to address the information need of resources needed then the tool would need to be able to identify social media data discussing what different “physical things” need to be available to address

whatever crisis event has occurred. For the damage information category, the tool needs to be looking for physical damage that has occurred as a result of some crisis. This could take the form of identifying destroyed utilities, homes, roadways, or other infrastructure. Knowing what specific information emergency managers require helps focus tool and platform development and ensures that the right questions are being asked and the right answers are being found.

The use of NLP methods for event identification adds to both the collection of tools that exist for event identification and gives further evidence that social media data reflects offline actions in the real world. Having the ability to summarize large data sets collected from social media, in this case Twitter, gives emergency managers the ability to examine that data quickly. The use of real time, time serialized sentiment scores and real time updating word clouds has shown that offline events can be identified through the examination of summarized Twitter data.

In addition to these primary contributions, three other additions to the research field have been made that are worth discussing. These include the design considerations produced by the semi-structured interview study, the data flow process created during prototype development, and an attempt and creating an event detection processes utilizing real time social media data.

Design Considerations

The Design Considerations provide a stepping off point for by those in the Crisis Informatics field. This stepping off point should aid in the development of tools and platforms that seek to utilize social media data in disaster and crisis response. Three key considerations have been proposed, Focus on the User, Focus on the Stage, and Focus on Reporting Needs. Created based on what was learned from the coding of the interview data as part of the study presented in Chapter 5, these considerations cover multiple areas of product design and development. The creation of the considerations was done in a way to indicate high level

concepts that should be included in social media analysis tools geared towards assisting with crisis and disaster response.

The first, Focus on the User, covers the beginning of the process where developers need to understand who their tool is being developed for. Having an identified "client" at the onset of product development focuses the tool for their use and provides a higher likelihood of adoption by the users. The second, Focus on the Stage, covers functions that the tool/platform should have to become useful for the identified users. The functions provided in any social media analysis tool need to be able to provide the information needed by emergency managers. No matter how "good" or accurate the analysis being performed is, if it isn't targeting the right information adoption by emergency managers is unlikely. The third, Focus on Reporting Needs, covers the end product that the tool/platform should provide to the users that have been identified. Any analysis conducted needs to be able to be interpreted by those who are going to use it to make decisions. The output of a completed analysis platform needs to give the user data in a familiar way that allows them to quickly access pertinent information. Additionally, being able to integrate new analysis tools into existing processes may speed up a potential user's adoption of the final developed product.

Data Flow

The Data Flow proposed in Chapter 6 moves through various steps that had needed to be completed while performing the Test Cases that were also proposed in Chapter 6. This data flow attempts to take raw data and turn it into actionable intelligence. Having a guide to build upon may assist other researchers in their attempts to utilize social media data across various applications. Alongside this data flow were the different data collection, processing, and analysis tools that were used while completing the different test cases also presented in Chapter 6. The use

of these tools and processes aids in the use of the data flow process, by providing samples of how data analysis can possibly take place. Examining the processes completed in this dissertation gives other researchers examples from which to build upon. Not having to start from scratch may provide those completing work in the future inspiration for other new ways to examine social media data for use in the crisis response process.

Event Detection

The ability to detect real word events through the examination of social media data provides emergency managers another avenue of responding to actual and potential crisis and disaster events. Even more useful, is building the ability to do so in a real time manner. The sooner that a problem in the world is identified the sooner the proper resources can be gathered and dispatched to deal with the problem. The utilization of social media data has shown to be a viable mean to detect events.

The three NLP methods that have assisted event detection with both real time and static data include term frequency analysis, sentiment analysis, and named entity recognition. Term frequency analysis was used to generate word clouds and n-gram lists. Sentiment analysis was used to create time-series graphs displaying sentiment data, and named entity recognition was used to create bar graphs of various identified entities. Most used for event detection were term frequency analysis and sentiment analysis. The use of these two methods in the ways that have been described in Chapter 6 led to the identification of real word events through the examination of both real time and static social media (Twitter) datasets. These real word events include announcements about Beaver Stadiums capacity for Football Games, a Russian attack against a Ukrainian shopping mall, and the landfall of a hurricane.

These different events were identified through the use of the data flow process, and the examination of the results of each test case. In these results, changes in the data were noticed in both topics of discussion and sentiment.

For the case of Beaver Stadium, change was noticed in terms that were appearing in word clouds that were being created in real time. A "status quo" state existed in the word clouds with terms being shown that had no real relation to either Penn State or State College, then terms and phrases appeared which had relevance to both Penn State and State College specifically in reference to Penn State's football team.

For the Ukraine case and the Hurricane Ian case, time-series sentiment graphs were generated and both outliers and level shifts were identified in the data. This change in sentiment data provided indications that something had happened that affected the content of the data being collected. When investigated, news sources had reported the attack on the shopping mall and the time of hurricane's landfall. These reports lined up in time with the times that the outliers and level shifts appeared in the time-series graphs. Along with the changes in sentiment, an increase in volume of Tweets collected was also noticed. This increase aligned in the same manner with the change in sentiment with the timing of real word events.

The work done that made up Chapter 6 of this dissertation shows the beginnings of an event detection method that utilized social media data. What is shown is that the content of conversations on social media are influenced by real word events. With further research and development, this mirroring can potentially be utilized to help emergency managers respond to crisis and disaster events.

Additional Applications

An important step in research is to consider the implications of a projects findings in tangential fields. The work completed in this dissertation was focused on the needs of emergency managers concerned with crises affecting their communities. That being said, other forms of emergency management exist with similar, yet differently focused goals. One of these other fields with emergency management professionals is the Hospital industry which has high stake in ensuring their continued operation in the case of emergency. Another field consists of corporate emergency managers who are also concerned with their businesses ability to continue operations during times of crisis.

Hospital Emergency Management

An essential part of operating a hospital is to have a plan exist ensure its continued operation in times of distress. Different types of disaster events have the potential to negatively impact the operation of a hospital, which becomes particularly dangerous as they are full of vulnerable people. The utilization of social media in a similar manner to what has been discussed in this dissertation could have applications in hospital emergency preparedness activities. Additionally, as hospitals exist as part of the emergency management and response process, having tools to aid in understanding a crisis can help them better prepare to meet the needs of those harmed by the crisis. The sooner a hospital is aware of some event that may begin to tax its resources, the quicker they can begin to gather what the need to meet the challenge.

The California Hospital Association lists a number of different “elements” that should make up an Emergency Operations Plan (*Emergency operations plan (EOP,)* 2017). These include Communications, Resources and assets, Safety and security, Staff responsibilities, Utilities, and Clinical support activities. The possibility exists to integrate social media analysis

processes into these elements, primarily with communications. Having multiple communication platforms to reach out to employees, patients, and community members increases a hospitals ability to understand the resources it has available to it and the resources it is able to provide to the public.

Corporate Emergency Management

Ensuring the continuity of business operations is vital for the long term success of any corporation. This idea has recently been put to the test with the impacts of the COVID-19 Pandemic that began in 2020. These impacts have been seen across virtually all industries, with various levels of success in response efforts. Also important to corporations is public engagement and understanding the publics views of the corporation. Social media data analysis has the potential to aid in both of these concepts.

Much like the needs of emergency managers, those ensuring business continuity need to be aware of different hazards and threats that may exist that could do harm to a business. Having the ability to pull information from social media can provide those working in this capacity with more data to make decisions. A specific topic/hazard that may be of interest to corporate emergency managers could be their company's public image. Being able to utilize social media analysis tools to identify how the public views their company could allow these managers to better confront public image and relation issues that could affect business operations.

Chapter 8

Discussion and Recommendations for Continuing Work

To finish this dissertation, various discussion points will be brought up and recommendations will be given for future work and research to continue adding to the Crisis Informatics field. These discussion and recommendations come from the experiences had and the lessons learned while completing this research.

The first of these discussion brings up limitations in the findings of this dissertations and some challenges that appeared while completing the work. These limitations and challenges influenced the manner in which this dissertation was completed and the interpretations of its findings. Following this, are two separate discussions that attempt to provide more context into the word in which emergency managers and first responders operate. The topics brought up in these sections focus on guiding how the work presented in this dissertation should be interpreted by others. The final discussion of this dissertation includes recommendations for work that should be conducted to follow on to the research presented here.

Limitations

As with all research, limitations emerged in the applications of this study's findings as the work was being completed. The primary limitation comes from the makeup of the final sample population. Referring back to Chapter 5, the sample population was made up of emergency managers that were contacted through a Facebook group and an email listserv. The makeup of these emergency managers ended up being primarily university and county level managers. Noticed in the interviews, many of these groups seemed to have limited staffing often

only having 1-3 permanent positions. These leads to the thought that it would be difficult for them to fully utilize social media analysis tools. Technical tools require training to properly utilize and those in the positions to utilize them often have many other preexisting responsibilities that they need to focus on.

From one interview with state level emergency managers, it is suspected that this level of operation may be a more successful user of social media analysis tools. They have more resources, personnel, and funding to make use of new and experimental tools. They also respond to and monitor larger scaled emergencies which may provide them better ways to test these tools. Along the same lines if an event does occur larger organizations have more ability to increase staffing and pull in new resources/staffing.

Similar to this issue, is the issue of development cost of tools. Any group that is trying to build tools for widespread use is going to need some way to pay for the development of the tools and likely want to recoup their costs. Although there are many emergency management groups across the country, how many of them can utilize these tools? A limited population to sell products to, could increase the price needed to recoup costs. This price increase could then limit how many groups could have access to any developed tools, furthering the issue of emergency management groups not being able to properly utilize social media analysis tools.

Challenges

One of the initial challenges that appeared during this research took place while trying to identify participants for the semi-structured interview study. Initially, some Facebook posts were made in an attempt to advertise to potential participants. These initial attempts were met with no responses. Eventually, progress was made when a member of the dissertation committee was able to utilize their contacts to get the advertisement sent out to better sources.

Another challenge appeared while conducting interviews. While obtaining questions the pre-created guiding questions was done successfully, the conversations had across the interviews remained primarily focused on these questions. The goal of using semi-structured interviewing was to hopefully illicit knowledge related to unknown topics. Limited success was achieved as most participants seemed to be content with focusing on the initial questions and did not seem to bring up new topics on their own. Separate from these challenges with the interview process were issues that appeared with data collection, social media reliability, and questions concerning the physical locations that social media content gets generated.

Social Media Unreliability

One of the primary issues that appeared during the completion of this research was the unreliability of a social media platform due to its nature of being privately owned. During the course of developing prototype tools that were utilizing data from Twitter, the platform was sold to a new owner which led to significant changes in its operation. Both technical and business changes were noted. When Twitter was sold in 2022 and rebranded to "X" in July of 2023 (Ivanova, 2023) many changes were noted. A new API version was released during this ownership change which affected how Twitter data was accessed. New monetary costs were also added to continue accessing the API. Additionally, an anecdotal change in the user base could be identified. This appears to be driven by a change in the content moderation process being updated under the new owners.

This leads to the thought that any social media analysis process should be capable of taking in data from multiple sources and not be reliant on one specific platform. Relying on an individual data source opens yourself to repeating the problem encountered in this research, the loss of data access. Having multiple sources of data allows for redundancy in the system. It also provides the opportunity to compare different sources against each other and then determine

which styles of social media may work best in the emergency management application. Additionally, the multiple sources of data may provide opportunity for cross validation. If you are finding the same information from different sources the chances of that information being accurate increases.

Adding to some reliability issues with social media data is the concern of not necessarily knowing where the data is physically coming from. At least in the case of Twitter, the overwhelming majority of collected data does not contain geotags or coordinate location metadata. This leads to the issue of not knowing where the data you are collecting is coming from when you are searching for data related to some topic. The primary concern with this is the lack of ability to determine if the data you are collecting is being generated by those being affected by the crisis in question or by those who are just talking about the crisis in question. Finding a way to make this determination would be a great help to the use of social media data during crisis response. Those using the data would then better be able to understand the context in which the data has been created. If they know it is coming from affected populations, then they know that data can be used build more situational awareness concerning the crisis event.

GIS Issues

Location plays an incredibly important role in the emergency management process. To solve problems created by crisis, managers and responders need to know where the problem is occurring. Naturally, this has led to the interest in the integration of geotagged social media data and different GIS platforms. This has the potential to greatly aid in the analysis of social media data by providing the different locations of the conversations occurring on social media. Twitter has different geotagging functions that allow users to attach different locations to their Tweets. Unfortunately, it has been shown that there is incredibly limited use of this function with less than three percent of Tweets containing a geotag (Elrod, et al., 2021). This limited use of geotagging is

the primary reason that the analysis tools developed and presented here make no attempt to utilize any sort of location analysis or mapping.

Other work has been completed that attempts to circumvent this issue. These works target secondary location markers that exist in the makeup of a Tweets metadata and a Twitter accounts attributes. First is the PIVOT platform that examines the different locations that a user attaches to their Twitter accounts to make judgements about where they may be tweeting from (Elrod, et al., 2021). Adding to this is Grace et al., (2017) who examined how the accounts that a Twitter user followed could tell an observer how likely they were to live in a specific area. He found that the more accounts followed that were local to any given area made it more likely that the account holder resided in that area.

The Truth of the Matter

In Chapter 5 comparisons were drawn between the information categories created based on the analysis of the coding process and FEMA's National Preparedness Goals. All of the information need categories seemed to match with the core capabilities laid out within the NPG and many of the other categories found matches as well. Considering this a coincidence would be lazy, and provide little in the way of a contribution to the academic field. To dispel the idea that the interviewees were prompted through the questioning to provide answers supporting the NPG, not once was the NPG mentioned by the interviewer to any of the participants. Thinking through these similarities though, leads to a decision tree of why these similarities exist.

Sitting at the top of this tree is the "findings" of the interview study matching up neatly with already proposed activities to properly prepare for disasters. From there two options emerge. First, some sort of "truth" was found through the interviews. This is the idea that FEMA's NPG correctly deduced the information required to build a prepared community. This was then

rediscovered through examining the use of social media by emergency managers and attempting to extract the information desires they had of it. Second, that all the participants interviewed had been "trained" by the NPG. This line of thinking assumes that the NPG possibly preemptively primed the participants into its line of thinking and that the findings of the interviews were then influenced by the NPG.

Normally, one would have to decide which of these branches holds more evidence. Both could possibly be argued as being true, and more studies could be completed to provide evidence for both sides. Rather than doing this here, another question is posed. Does it matter? That is, whether or not some objective truth was discovered or that latent training biases were discovered, the participants want the information that they want.

The goal of this research was to aid Emergency Management Personal in their mission. To do so, information that they desire needs to be provided to them in a manner that they can utilize it. It makes no difference whether or not the information the desire comes from a universal truth about what is needed for disaster response or from years of training and education produced by other parties.

Responders vs. Decision Makers

When conducting any research that is concerned with aiding in disaster response it is important to identify who it is you are trying to aid early on in the process. For crisis informatics, this distinction will assist in understanding who your studies benefit. Two of the main groups that could be focused on in crisis informatics research that should be distinguished from each other are Responders and Decision Makers.

These two groups need to be separated as they have very different operational goals and requirements. For this discussion Responders are considered the "boots on the ground" workers

such as police officers, firefighters, and EMS personal. Decision Makers are considered those "in the background" such as emergency managers, PSAP managers, and others who work in more traditional office settings.

The research presented in this dissertation falls into the category of assisting Decision Makers. The nature of data collection and analysis does not fit well with the fast paced needs of Responders. The nature of Responders work is to receive information about a problem somewhere in the world that needs to be solved as soon as possible. They receive an address and description of the problem and then utilize their training and tools to go and solve that problem. Decision Makers focus on identifying the problems and identifying what different resources are necessary to solve the problems. Social media analysis appears to be more useful for these Decision Makers and their operations than for Responders operations. A fire engine responding to a call about a house fire won't have time to examine the internet for information related to the emergency, and there likely wouldn't be anything posted quickly enough anyways. An emergency manager operating in an EOC after an earthquake may be able to use social media analysis tools to identify posts about people trapped in buildings resulting in their ability to dispatch fire and rescue services to those who need them.

Continuing Work

As with all research there is always more that could be done and that should be done. A few different avenues exist for research that should be conducted that builds up the work that has already been done. Included in this is the development of a prototype that combines some of the data collection, analysis, and presentation processes presented in this dissertation and the conduction of some simulation or scenario to further test the use of these processes.

The first of these, building an analysis platform, was one of the original goals of this research when it was first proposed. Having not met that goal, it is important to state that it should still be completed at some point in the future. Understanding what emergency managers want from social media as a data source is a vital part of providing them useful tools, and this step should be built upon so that they can indeed begin to utilize social media. Next, is the creation and running of simulations to test the created analysis platform. It would be improper to attempt to provide untested materials to those working in the emergency management field. Those in the field make decisions that impact the health and safety of populations across the word. The nature of their work requires that the tools they used be proven to work and provide useful information to aid in their response efforts.

Building an Analysis Platform

One of the original goals of this research was to build out a prototype social media data analysis platform. This goal was not met in its entirety and should be the focus of research in the future. A ground work exists in Chapter 6 showing that NLP methods can be successfully used to analyze collected Twitter data and that interpretations can be made based on that analysis. This ground work should be built upon to better test and show the use of social media data during crisis events. Alongside further development of Twitter collection and analysis, other social media platforms should also be targeted for research. Having multiple sources of information/data adds to the situational awareness picture and provides opportunities to validate analysis findings. Potential platforms that exist for data collection include Facebook, Instagram, Snapchat, WhatsApp, and more traditional news feeds/websites.

The construction of this analysis platform should focus on the following three topics during its construction: A focus on real time data, the integration of analysis methods, and the use

of statistical identification to create alert systems. The utilization of these different ideas will aid in the creation of a useful tool that can aid emergency managers in their operations.

Real time

While considering how to construct a social media data analysis platform, a focus should be given to utilizing real time data. This will make it more attractive to emergency management practitioners rather than attempting to give them tools that look at static or historical data. The more current information that a decision maker has related to a crisis the better they can update their response processes to react to the crisis.

Integrate methods

A single NLP method alone, while interesting, does not provide a complete picture of what information is being created on social media during crisis events. Analysis platforms should utilize multiple methods simultaneously. Each chosen analysis method should take data from the same source and provide different information about said data. The combination of methods acts twofold. First it allows for multiple categories of information to be provided to emergency managers at the same time; second, allows those emergency managers to leverage the different categories of information against each other to give themselves more context related to the event being examined.

An example of how this could be implemented is to integrate a sentiment analysis tool and an n-gram generation tool. To start, you could have you real-time sentiment analyzer producing some form of line graph where average sentiment scores are being displayed in a time series. A function could be added to allow a user to select some portion of time in that time series and have the top n-grams presented, providing text summary along with the sentiment graph. This would allow for a user to be able to notice a point of interest in the sentiment, and then potentially

identify the topics being discussed to produce that point of interest. Additionally, you could produce updating word clouds alongside the time-series sentiment graph. Having the word clouds update at the same rate as the sentiment graph would provide information on the topics being discussed alongside the sentiment scores.

Statistical identification/alert systems

Alongside the combination of NLP methods, users of a social media analysis tool would be greatly aided by some form of alert system or statistical method of identifying points of interest in data. At the current time much of the interpretation of the output of the various NLP methods that have been used has been through the visual examination of produced graphs and tables. This examination was done to look for outliers, level shifts, and topic changes as possible indicators of an event that has occurred.

Running statistical tests on the output of the chosen analysis methods has the ability to better identify changes in data. This can lead to the identification of information that would aid someone using the analysis tool. Efforts towards testing different statistical methods was begun alongside the primary research activities presented in this dissertation. These efforts were focused towards creating a sample alert system that monitored the output of the VADER sentiment analysis tool.

This potential alert system utilized standard deviations that would calculated from sentiment scores created on a Twitter dataset. A portion of a data-set was set aside as “test data” and a standard deviation was created for this portion of data. After the standard deviation was created, a process was created to identify sentiment scores that fell outside the standard deviation. The scores that fell outside the standard deviation would then set of an “alert” that a change in the data was detected.

Running Simulations/Scenarios

In addition to completing the development of prototype tools, simulations or scenarios should be executed to test the tools. This allows for the tools to be tested in a safe and ethical manner, where people are not being put in harm's way for the sake of product development. It also gets rid of the need to wait for a real word disaster to occur, and the requirement to be constantly monitoring for one in order to begin the testing of any developed tool.

In order to run any simulations or scenarios different resources will be required. These include the tool/platform being tested, data to test the tool with, personnel to operate the tool/platform, and researchers to monitor the simulation/scenario and evaluate the tool/platform. The first and last of these resources can be filled by the researchers who carry on with this work. Different options exist to obtain the second and third resources. In the completion of this dissertation many different Twitter datasets were collected that could be deemed appropriate to use as test data. Also, the CrisisFACTS platform discussed in Chapter 2 presents an opportunity to obtain test data and an additional way to validate the results of any simulation or scenario run. As for personnel to operate the tool/platform, opportunities exist within the emergency management offices of the Pennsylvania State University and the Centre Region council of governments. Both organizations would likely be open to working with researchers to test out new information gathering methods, and have worked with students in the past.

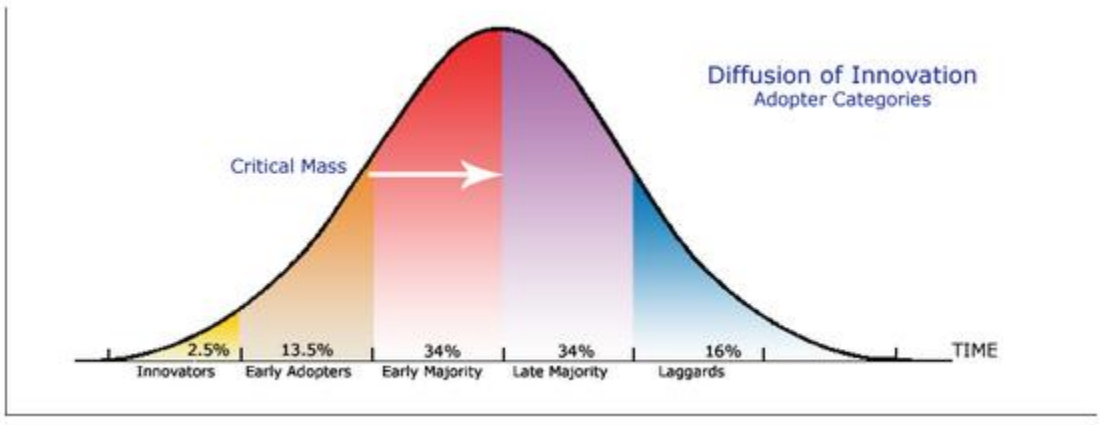
Alongside the creation of simulations to test tools, more interviews could also be completed to strengthen the information available to develop analysis tools and the processes to test them. These interviews should target larger scale emergency management organizations as the current set of interview data indicates that they have more potential to make use of social media analysis tools.

Diffusion of Innovations

As this research is concerned with the creation of new technologies and the introduction of new procedures and information use to the crisis response processes, the adoption of these new processes becomes important. To assist in the creation of future research, the examination of where current social media use falls into the Diffusion of Innovations framework may prove valuable. Figure 29 below displays five different categories of adopters.

Each adopter type describes a group of people and how quick they are to adopt a new idea. Innovators are generally the first people to test out new concepts and are not afraid to take on new risks. They are followed by the Early Adopters who enjoy change and are willing to try out new ideas. The Early Majority are those who will adopt new ideas once they begin to see the successes of these ideas. Following, are the Late Majority who do not like change and need to see proof of a new ideas worth. Finally are the Laggards who are the least likely to adopt new ideas due to comfortability with how things are (LaMorte, 2022).

Figure 29: Diffusion of Innovations from Kaminski (2011)



In the case of this research a different ideas of adoption exist. First, there is the concept of general social media use by emergency management. This is inclusive of social media usages such as the publishing of preparedness information by public information officers. Second, would

be the idea of social media use as an information gathering tool. The different test cases from Chapter 6 are examples of this. The further study of where different emergency management organizations exist as adopters may aid in the creation and adoption of social media analysis tools for them.

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Participant 2, interview by Christopher J. Doty, Aug 15, 2022, interview 2, transcript and recording

Participant 3, interview by Christopher J. Doty, Oct 14, 2022, interview 3, transcript and recording

Participant 4, interview by Christopher J. Doty, Oct 28, 2022, interview 4, transcript and recording

Participant 5, interview by Christopher J. Doty, Oct 28, 2022, interview 4, transcript and recording

Participant 6, interview by Christopher J. Doty, Oct 28, 2022, interview 4, transcript and recording

Participant 7, interview by Christopher J. Doty, Feb 22, 2023, interview 5, transcript and recording

Participant 8, interview by Christopher J. Doty, Feb 23, 2023, interview 6, transcript and recording

Participant 9, interview by Christopher J. Doty, Feb 28, 2023, interview 7, transcript and recording

Participant 10, interview by Christopher J. Doty, Feb 28, 2023, interview 8, transcript and recording

Participant 11, interview by Christopher J. Doty, March 3, 2023, interview 9, transcript and recording

Participant 12, interview by Christopher J. Doty, March 6, 2023, interview 10, transcript and recording

Participant 13, interview by Christopher J. Doty, March 10, 2023, interview 11, transcript and recording

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Appendix A

Interview Materials

Consent for Exempt Research

The Pennsylvania State University

Title of Project: *Social Media Requirements: Assessing Emergency Management's Expectations of Social Media as a Data Source*

Principal Investigator: *Christopher J. Doty*

Telephone Number: 814-308-3484

You are being invited to volunteer to participate in a research study. This summary explains information about this research.

- We are asking you to be in this research because of your role in emergency management and crisis response. The goal of this study is to uncover the needs that emergency management professionals have of social media data.
- The procedure for this study involves conducting an individual interview with you either in-person or over the phone. The interview will last approximately one-two hours. This interview will be audio recorded (if permission to do so is granted by you), in order for researchers to gain detail and accuracy from the discussions.
- In order to protect confidentiality, only the research team will have access to the names of participants. Data will be securely stored on the principal investigator's password-protected computer. In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared. We will do our best to keep your participation in this research study confidential to the extent permitted by law. However, it is possible that other people may find out about your participation in this research study

If you have questions or concerns, you should contact Christopher Doty at 814-308-3484. If you have questions regarding your rights as a research subject or concerns regarding your privacy, you may contact the Office for Research Protections at 814-865-1775. Your participation is voluntary and you may decide to stop at any time. You do not have to answer any questions that you do not want to answer.

Tell the researcher your decision regarding whether or not to participate in the research.

Interview Advertisement

Hello,

I am a PhD Candidate at the Pennsylvania State University. My area of focus is the field of Crisis Informatics which is the study of the use of information and data during crisis and emergency mitigation, planning, response, and recovery. Specifically, my research is concerned with the rising use of social media by both the general population and emergency response organizations during crisis situations.

Part of this research includes conducting a number of interviews with personnel who work either directly with or tangentially to emergency management organizations. Ideally, participants would have experience working in Emergency Operations Centers and/or Public Service Answering Points. The overall subject of the interviews would be concerned with learning about your experiences working with social media and any desires you may have to use social media in your operations.

If you would be interested in participating in this research project, please fill out the google form linked below.

Very Respectfully,

Christopher Doty
Ph.D. Candidate, Informatics
The Pennsylvania State University

Social Media Requirements Background

My name is Christopher Doty. I am an Informatics PhD candidate with the College of Information Sciences and Technology at Penn State University. Within the field of Informatics my focus in on crisis informatics. Our field is concerned with the intersection of society and technology and how that interaction plays out during crisis situations. Currently, I am conducting research within the Communication, Information, and Navigation Office at The Penn State Applied Research Lab. My research is related to the use of social media platforms before, during, and after crisis situations such as, but not limited to: natural disasters, terrorism, and civil unrest.

My interest in this field began with a research project as an undergrad where we were tasked with integrating the geolocation features of Twitter with a GIS platform provided to us. We were attempting to see if geo-located Tweets could be used to assist in understanding the effects of the damage caused by a Hurricane. More recently I have worked on projects examining the use of Twitter during the Covid-19 pandemic. Work was done investigating offering behavior of Twitter users to assist in the supply and acquisition of PPE items that were in high demand and short supply. Additionally, correlations between sentiment toward the pandemic and case rates were searched for using Twitter data collected through geo-fencing.

This interest has led me to investigating Twitter usage as part of my dissertation. For my dissertation I am seeking to design an analysis platform for emergency management organizations. This platform would ingest social media data feeds and then provide the derived intelligence to the consumer. The beginning of this project involves taking a step back from direct analysis of social media data and asking the question: “What is really needed and how should it be presented?” This is where this interview comes into play.

There are four overarching goals of this interview process. First is to evaluate your specific expertise. As an emergency response professional, you understand what events transpire during different phases of the crisis response process. As such, your experiences are extremely relevant to any sort of research in the emergency/crisis response field. Learning about these experiences allow us to understand the background that influences your responses to the interview questions. Your experiences will help us tailor our interpretation of the discussion to better utilize the information we learn from you. It will also better allow us to classify what situations/fields may be more or less suited to utilizing social media. This will aid in the targeting of our analysis platform design.

The next goal of this interview is to learn about your previous interactions with social media as part of your role in the emergency management/crisis response processes. We would like to know about what sort of platforms you have used, how you have used them and why you used them. Understanding your experiences with social media platforms will help provide some context to the answers provided during the interview process. If

necessary, some examples can be provided of various uses of social media to assist in giving the interview questions a better framing. If you have never used social media before that is also ok. It gives us the opportunity to introduce a new topic and get some reactions from a potential new user.

Following this is to build and understanding of what, if anything, you believe is important about social media and its interaction with crisis response. That is, to find out what you would like from it as a data/information source during your operations and how it might be used to assist with your decision-making process. Discovering what you believe is important, when you believe it is important, and who it is important for is vital in the task of capturing information from social media platforms. The collection of data from social media can change drastically based on what is needed, and the more focused the collection is the more likely something interesting/relevant will be found. After this information is gathered, then its presentation can be better targeted towards those who will use it.

Last is to discuss how any finalized analysis platforms should present the data they are examining. The best analysis in the world can be completed but if it is not presented in a usable way then it may have well not been done. Discussing how you are used to having information provided to you to make decisions will allow for our final platform to better aid you. Included in this is also discussing who is being presented the analysis and for what purposes. As with how what from social media is important affects what is collected so does how it will be used. Understanding the end goal of social media's use in crisis response context influences what sort of analysis needs to be completed. Along with this is who is using the analysis platform. Different job types require different information. Knowing who the users are going to be means the information can be provided in a more intuitive manner.

Thank you for taking the time to read this background information. If you would be willing to discuss this information further and participate in my study, please let me. I look forward to speaking with you soon and hope this helps you prepare your thoughts.

INTERVIEW FORM

INTERVIEWEE NAME			**CONDUCTED BY**	Christopher J. Doty	
INTERVIEW DATE		**INTERVIEW START TIME**		**INTERVIEW END TIME**	
INTERVIEWEE TITLE			**INTERVIEWEE ORG**		
INTERVIEWEE BACKGROUND					

At what scale do you operate at with your organization? Populations size, avg. impact, size of response, etc…	
Have you used social media as part of your operations in the past? In what context?	
What platforms have you used? How have you used them?	
What prompted your use of social media/the chosen platforms?	
What potentially interests you about social media as a data source if you have not used it in the past?	
What communication directions do you see social media best utilized in?	

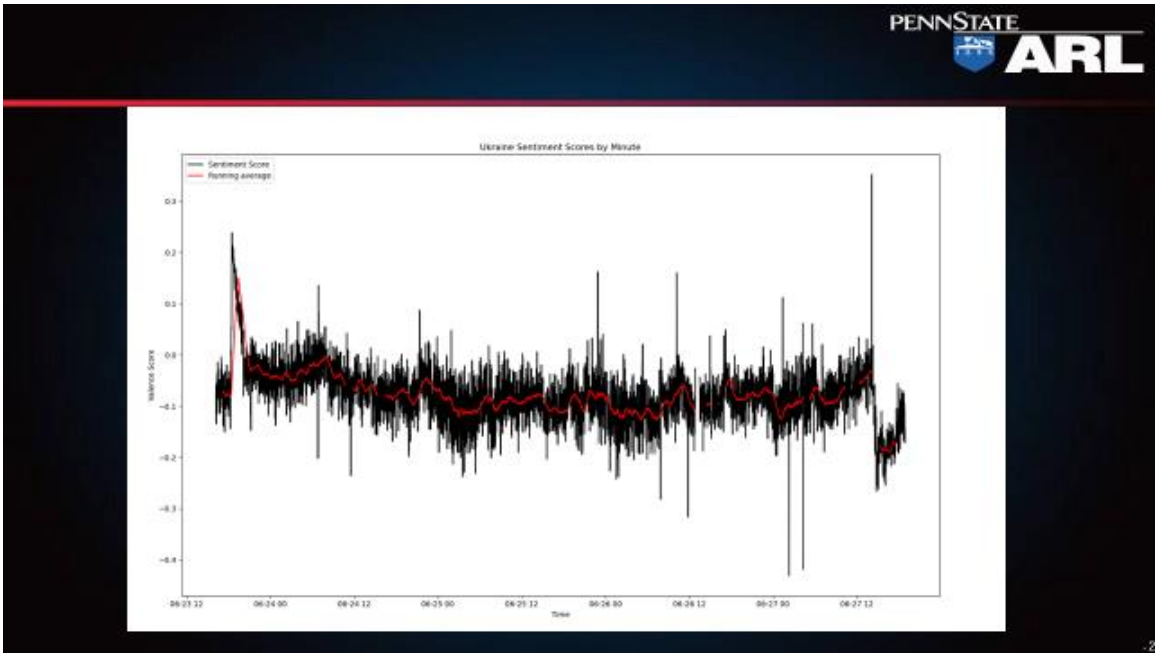
If you theoretically had access to the whole of social media what would you want to see?	
What information gaps have you noticed exist in previous operations?	
How would you like this information presented to you?	
Who would this information be provided to?	
What types of events do you believe this information would be most useful? At what scales?	
Which stages of planning/response do you believe social media data to be most interesting/useful?	

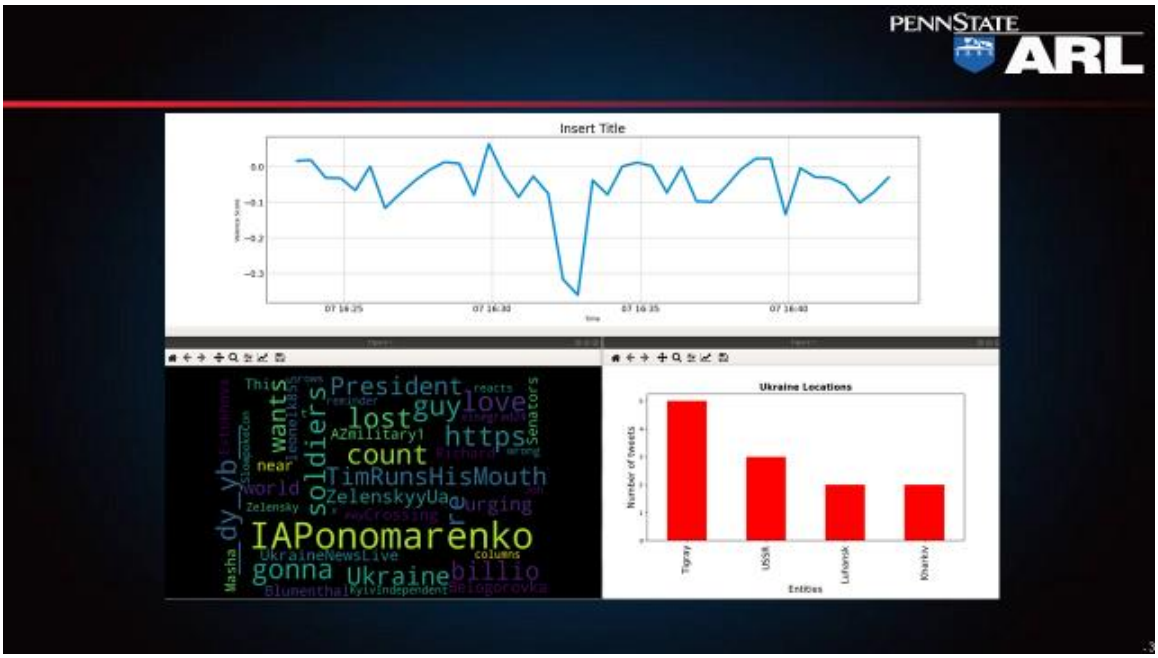
ADDITIONAL COMMENTS

INTERVIEWER NAME	TITLE	SIGNATURE	DATE
Christopher J. Doty	PhD Candidate, Informatics		

Interview Presentation

The slides shown below were utalized durring the semi-structred interview process. They were used to show the different participants the results of different social media data analysis processes.




PENNSTATE
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TimRunsHisMouth
ZelenskyyUa
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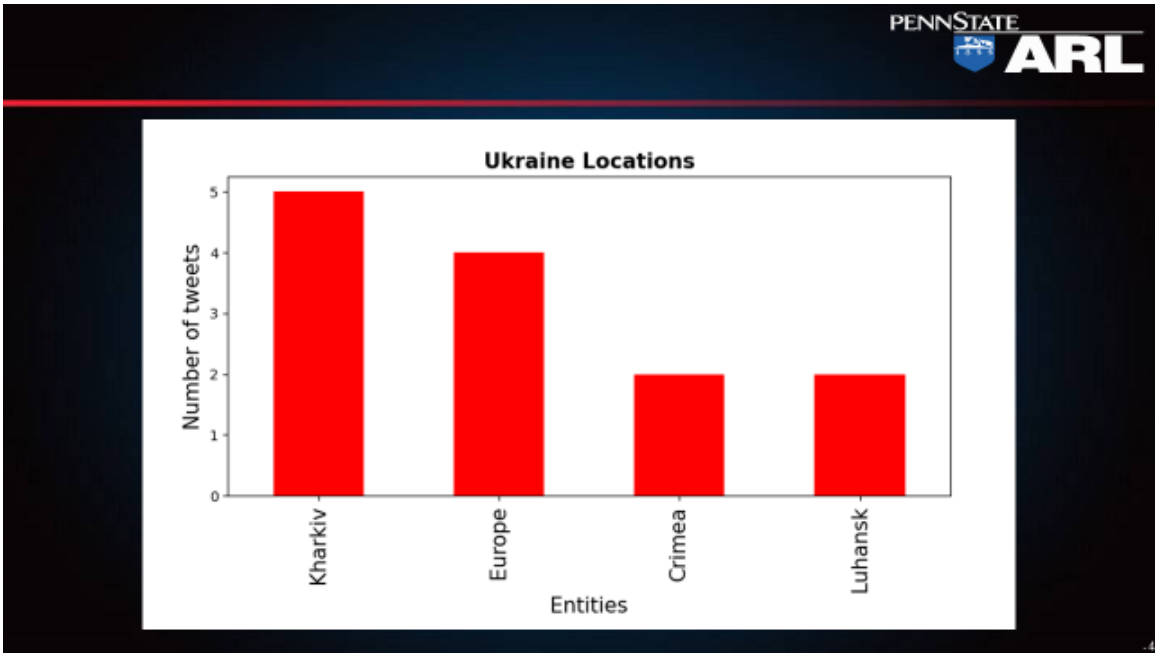
Ukraine
billio
Ukraine Locations
Number of tweets
Entities
Tigray
USSR
Luhansk
Kharkiv


PENNSTATE
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Number of tweets
0
1
2
3
4
5
Kharkiv
Europe
Crimea
Luhansk
Entities


PENNSTATE
ARL
tzimmer_history
Ohio
Located
Football
heart
Arizona
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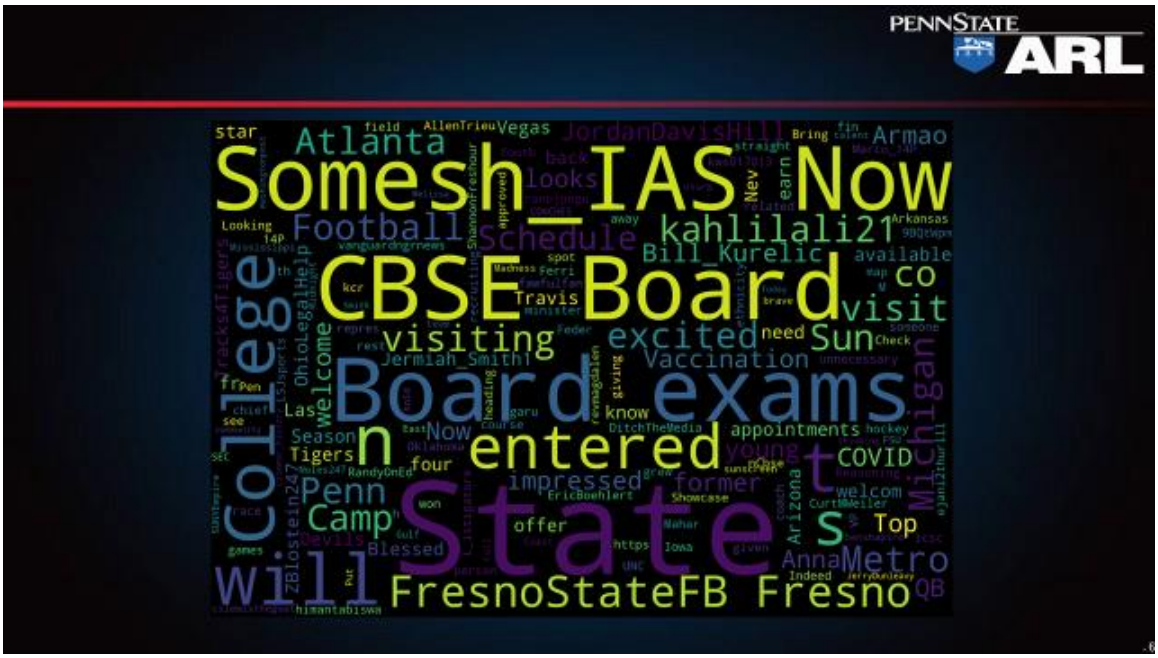
filled
Now
CBSE
SAHomebuilder
college
IDGAF
Jimbo
entered
Somesh_IAS
check
Season
exams
ranked
finally
applicants
shouldn
Board
Sun
chat
Tof
Devils
State
Kirby
Stadium
ou
June
https
fall
RobertJ3nnings
arrived
Fresno
columns
rows


PENNSTATE
ARL
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Atlanta
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JordanDavisHill
Armao
Somesh_IAS_Now
Looks
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schedule
kahlilali21
Arkansas
Bill_Kurelic
available
College
CBSE_Board
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Travis
visiting
excited
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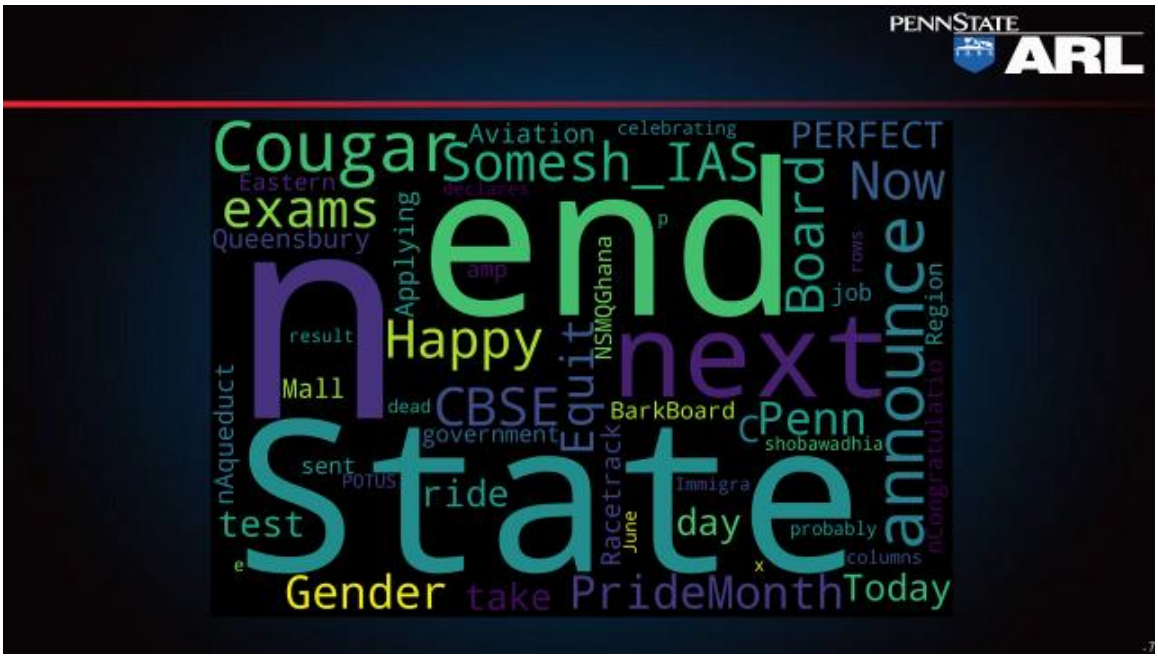
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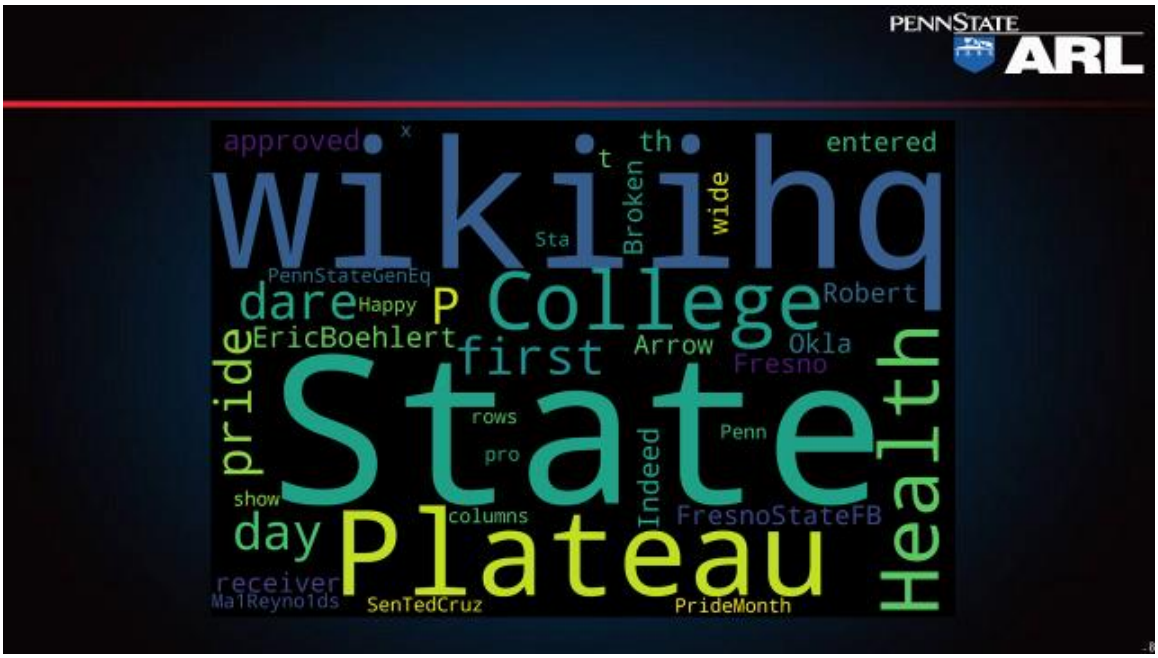
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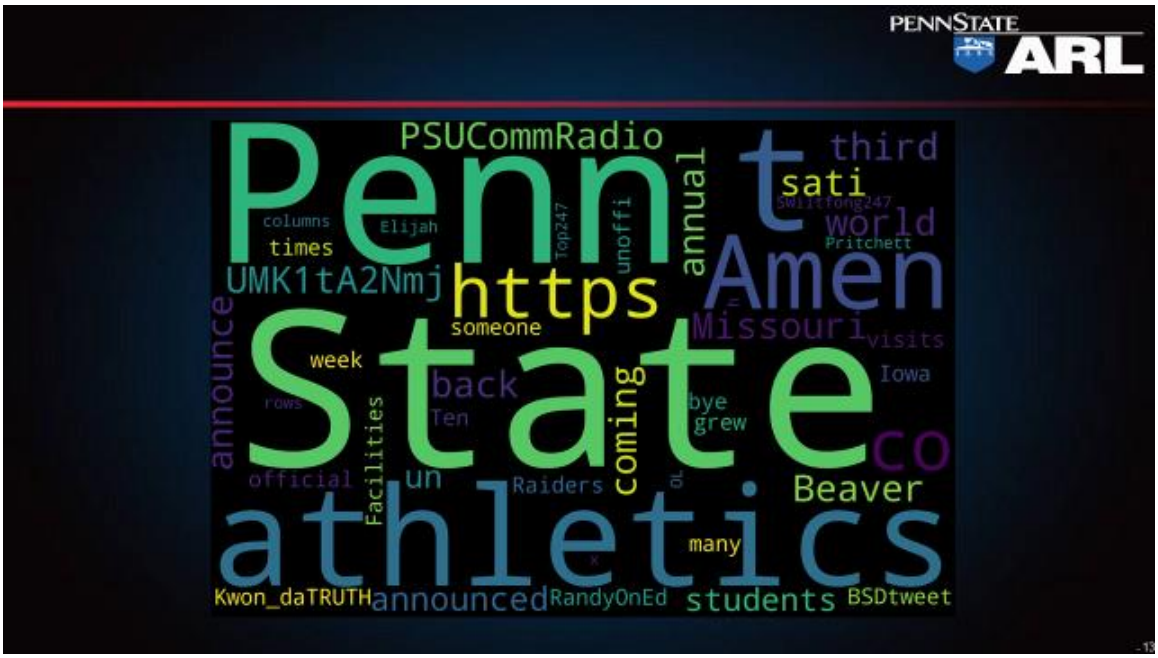
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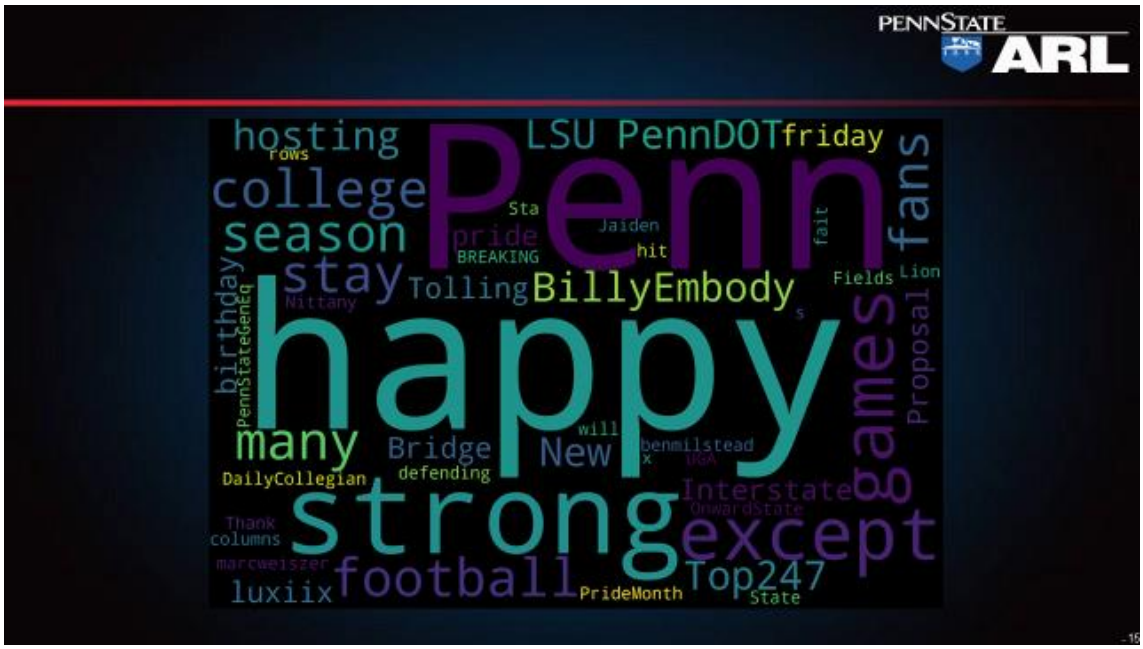
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IRB

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Office for Research Protections
Human Research Protection Program
Office of The Senior Vice President for Research
The Pennsylvania State University
205 The 330 Building
University Park, PA 16802

814-865-1775
irb-orp@psu.edu
research.psu.edu/irb

EXEMPTION DETERMINATION

Date: May 20, 2022

From: Stephanie Flohr, PhD, IRB Analyst

To: Christopher Doty

Type of Submission:	Initial Study
Title of Study:	Social Media Requirements: Assessing Emergency Management's Expectations of Social Media
Principal Investigator:	Christopher Doty
Study ID:	STUDY00020248
Submission ID:	STUDY00020248
Funding:	Applied Research Laboratory (UNIVERSITY PARK)
Documents Approved:	• Abstract.docx (0.01), Category: Sponsor Attachment • HRP-591 - Protocol for Human Subject Research(1).pdf (0.02), Category: IRB Protocol • Interview questions.docx (0.01), Category: Other

The Office for Research Protections determined that the proposed activity, as described in the above-referenced submission, does not require formal IRB review because the research met the criteria for exempt research according to the policies of this institution and the provisions of applicable federal regulations.

Continuing Progress Reports are **not** required for exempt research. Record of this research determined to be exempt will be maintained for five years from the date of this notification. If your research will continue beyond five years, please contact the Office for Research Protections closer to the determination end date.

Changes to exempt research only need to be submitted to the Office for Research Protections in limited circumstances described in the below-referenced Investigator

PennState

Office for Research Protections
Human Research Protection Program
Office of The Senior Vice President for Research
The Pennsylvania State University
205 The 330 Building
University Park, PA 16802

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irb-orp@psu.edu
research.psu.edu/irb

Manual. If changes are being considered and there are questions about whether IRB review is needed, please contact the Office for Research Protections.

Penn State researchers are required to follow the requirements listed in the HRP-103 – Investigator Manual, which can be found by navigating to the IRB Library within CATS IRB (http://irb.psu.edu).

Investigators are responsible for reviewing the History tab of their STUDY in CATS to ensure that any administrative HRPP requests are addressed in a timely manner.

This correspondence should be maintained with your records.

VITA

CHRISTOPHER J. DOTY

EDUCATION

Cohort 2019 — Doctor of Philosophy in Informatics, *The Pennsylvania State University*

Earned May 2017 — Bachelor of Science in Security and Risk Analysis, *The Pennsylvania State University*
Minor in Information Sciences and Technology

RESEARCH/TEACHING EXPERIENCE

January 2020 – Present — Graduate Research Assistant, *Applied Research Laboratory, The Pennsylvania State University*

- Conducted Semi-Structured Interviews with Emergency Managers and other professionals in the Emergency/Crisis response field
- Prototyped social media collection and analysis tools that utilize Natural Language Processing to summarize, quantify, and visualize large text datasets
- Completed Dissertation study that investigated the requirements and uses of social media data for Emergency Management processes

August 2019 – December 2019 — Teaching Assistant, *College of Information Sciences and Technology, The Pennsylvania State University*

- TA for SRA 468 – Spatial Analysis
- Graded weekly assignments and midterm/final exam
- Answered questions during completion of lab assignments
- Held weekly office hours to assist with weekly assignments and term projects
- Provided guidance for selection of term project subject

PROFESSIONAL HISTORY

January 2024 – Present — Engine Lieutenant, *Alpha Fire Company*

- Act as a company level officer responsible for 2-4 firefighters while conducting firefighting operations
- Tasked with the instruction of probationary members in fire engine company tactics

September 2020 – December 2023 — Firefighter, *Alpha Fire Company*

- Tasked to protect the lives and property of the citizens we serve in a professional and competent manner

August 2017 – May 2019 — Test Analyst, *Cognizant Technology Solutions*

- Member of L3 Support team for a point-of-sale software
- Used SQL to work with databases related to the point-of-sale software
- Troubleshot issues with point-of-sale software the L2 team could not handle
- Interacted with employees to figure out problems with the software
- Assisted in deploying software updates
- Installed and verified point of sale and other relevant software on new machines for computer replacement or new store set up
- Trained in different testing methods (Performance testing, functionality testing, etc…)