Human Dynamics in Smart Cities
Series Editors: Shih-Lung Shaw · Daniel Sui

Shih-Lung Shaw
Daniel Sui *Editors*

Human Dynamics Research in Smart and Connected Communities

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Human Dynamics in Smart Cities

Series editors

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This series covers advances in information and communication technology (ICT), mobile technology, and location-aware technology and ways in which they have fundamentally changed how social, political, economic and transportation systems work in today's globally connected world. These changes have raised many exciting research questions related to human dynamics at both disaggregate and aggregate levels that have attracted attentions of researchers from a wide range of disciplines. This book series aims to capture this emerging dynamic interdisciplinary field of research as a one-stop depository of our cumulative knowledge on this topic that will have profound implications for future human life in general and urban life in particular. This book series plans to cover topics from theoretical perspectives, space-time analytics, modeling human dynamics, urban analytics, social media and big data, travel dynamics, to privacy issues, development of smart cities, and problems and prospects of human dynamics research. We invite contributions of theoretical, technical, or application aspects of human dynamics research for a global and interdisciplinary audience.

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Daniel Sui is Arts and Sciences Distinguished Professor and Professor of Geography, Public Affairs, Public Health, and Urban/Regional Planning at the Ohio State University (OSU). Since July 2016, he has been on an IPA assignment to serve as the Division Director for Social and Economic Sciences (SES) at the US National Science Foundation. Prior his current appointment, Daniel Sui served as Chair of Geography (2011–2015) and as Director of the Center for Urban & Regional Analysis (CURA) (2009–2012) at OSU. He holds B.S. (1986) and M.S. (1989) degrees from Peking University and Ph.D. degree from University of Georgia (1993). His current research interests cover issues related to robust and reliable practices in spatially integrated social sciences and humanities, human dynamics in smart & connected cities, and location-based social media. Daniel Sui was a 2009 Guggenheim Fellow, 2014 Google Faculty Fellow, and 2014 recipient of the distinguished scholar award from the American Association of Geographers. Sui was also the 2015 Public Policy Scholar in residence at the Woodrow Wilson International Center for Scholars. More information about Sui's current research can be found at: https://www.researchgate.net/profile/Daniel_Sui.

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Chapter 1
Introduction: Human Dynamics in Perspective

Shih-Lung Shaw and Daniel Sui

1.1 Introduction

Human dynamics have been in existence as long as the human history. The topic has been studied by researchers in many different disciplines over time. One characteristic of human dynamics is that they evolve with the changing environments, technologies, and human societies. Human dynamics in today's world are very different in many aspects from how we carried out our activities and interactions even a few decades ago. There are many factors contributing to the changing human dynamics. During the last three decades, advances in modern technologies such as information and communication (ICT) technology, location-aware technology, sensor technology, and mobile technology have played an important role in changing human activity and interaction patterns. For example, smartphones have enabled us to stay connected and interact with other people through a wide range of services and information available on the Internet to carry out various activities. Although the basic human needs have stayed the same as they were before, the ways we fulfill these activities have changed significantly due to modern technologies. It is now feasible to complete many office tasks from anywhere with an Internet connection and an appropriate device. When we are looking for a dinner place, we can quickly find a restaurant recommended by people we do not know via an app on our smartphone. We can walk to a bus stop just in time to catch a ride since the real-time bus locations are available at our fingertip. There is no doubt these changing human behaviors are leading to different kinds of dynamics in the urban, economic, transportation, social, and cultural systems.

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However, our knowledge about the implications of these changing human dynamics to our communities and societies is still limited.

Modern technologies not only have introduced changes to human dynamics but also have enabled our capability of collecting detailed data about human dynamics. Facebook knows who our friends are, how we interact with our friends, along with the timeline of our activities. Amazon keeps track of what we buy, how frequently we buy different items, and even the items we browsed. Google can use the keywords in our Gmail messages to help with targeted advertising. We also use Twitter, YouTube, Instagram, Foursquare, OpenStreetMap and many other apps to contribute information voluntarily. They are generally known as Volunteered Geographic Information (VGI) or crowdsourced data (Sui et al. 2013). Mobile phone service providers know where we have been, when we were there, whom we have contacted, and how frequently we contact various people through our communication records. Our bank knows what we buy, where and when we buy them, and how much we pay for each item through our credit card transactions. Although we normally do not intend to publicize our activities, data are nonetheless collected, analyzed, and even shared publically. Even we do not use a smartphone or any of the modern ICT devices, our data still can be collected via modern technologies. For example, an increasing number of security cameras mounted in public spaces can take pictures of passing people and vehicles. Through image processing plus facial recognition and license plate number matching software, people and vehicles can be identified and tracked. With cameras mounted on drones, privacy in our own fenced backyard also is in danger. Furthermore, our friends can post pictures of us on Facebook or Instagram even we do not use those apps. It therefore would be naïve to assume that we still have the same level of control of our privacy in today's world as we were a few decades ago. The reality we face today is a matter of who have our data and how they are using our data! In other words, it is out of our control to a great extent. This is part of the life we have to deal with in the Big Data era (Manyika et al. 2011). One challenge to human dynamics research community is how we can use the unprecedented data collection via various sources to help us gain insights on human dynamics in order to answer important questions to our communities and societies and make smart decisions for a better future of our communities and societies.

Human dynamics research faces many challenges of addressing complex human-technology relationships and interactions, deluge of data related to different aspects of human dynamics, and transdisciplinary challenges that involve natural sciences, social sciences, humanities, and engineering. It is not feasible for one edited volume to cover all of these issues. This edited volume instead is intended to contribute to human dynamics research through a collection of papers which focus on selected innovative approaches, data issues, method development, and empirical studies mainly from geographic and spatiotemporal perspectives. A Symposium on Human Dynamics Research consisting of twenty-five paper and panel sessions was organized at 2016 American Association of Geographers (AAG) annual meeting in San Francisco, California. An open call for papers was announced to a wider research community. The chapters in this edited volume are selected contributions from the Symposium and the open call.

1.2 Human Dynamics in Perspective

A legitimate question to ask at the beginning of this edited volume is: what is the precise meaning of human dynamics? Human dynamics have been studied in many different disciplines such as business, geography, physics, planning, psychology, sociology, among others. Each discipline tends to have its own perspective that leads to somewhat different research focuses. Jay Forrester, who was recognized as the founder of system dynamics, published three well-known books—*Industrial Dynamics* (Forrester 1961), *Urban Dynamics* (Forrester 1969), and *World Dynamics* (Forrester 1971). Forrester discussed computer simulation models in these books to shed light on the interactions among various elements for industrial management, urban issues, and the world system, respectively. Although the computer models proposed by Forrester offered useful tools for evaluating different strategies and policies, they were criticized for using a "systems analysis" approach to simulating social problems. For example, the computer simulation in the *Urban Dynamics* book was criticized by not considering that short-term gains might be desirable even at the price of long-term loss (Hester 1970). This suggests some shortcomings of using system dynamics approach to addressing social policy issues. The System Dynamics Society describes system dynamics as "a computer-aided approach to policy analysis and design. It applies to dynamic problems arising in complex social, managerial, economic, or ecological systems—literally any dynamic systems characterized by interdependence, mutual interaction, information feedback, and circular causality." (http://www.systemdynamics.org/what-is-s/) Human dynamics appear to be covered under this definition despite the weaknesses of tackling social issues using a system dynamics approach.

Wikipedia suggests that "Human Dynamics as a branch of statistical physics: Its main goal is to understand human behavior using methods originally developed in statistical physics." (https://en.wikipedia.org/wiki/Human_dynamics) This definition reflects a particular research direction of human dynamics that was inspired by Barabasi's (2005) publication of "The origin of bursts and heavy tails in human dynamics" in *Nature*. This article points out that most human dynamics models in various disciplines assume that human actions are randomly distributed in time. However, Barabasi's (2005) study indicates that individuals often execute tasks based on some perceived priority with bursts of rapidly executed tasks separated by long periods of inactivity, which results in heavy-tailed distributions. This line of research has influenced some human dynamics studies by geographers and geographic information scientists.

Seagal and Horne (2003), on the other hand, suggest that "Human Dynamics is a body of work that identifies and illuminates innate distinctions in the way people function as whole systems that include mental, emotional, and physical dimensions." The mental principle is related to mind and expressed in thinking (i.e., rational). The emotional principle is about forming relationships and expressed by making connections (i.e., relational). The physical principle is the practical part and expressed by doing and making things (i.e., pragmatic). All three principles are active in all people with various combinations and to varying degrees. This perspective of human dynamics places an emphasis on individual personality.

Human dynamics is a less frequently used term than other closely-related terms such as human interaction, human mobility, or human movement in geographic literature. One early use of "human dynamics" is found in Finch's article of "Geographic science and social philosophy" in the *Annals of the Association of American Geographers*, which states that "It is obvious that many of the elements of regions are observable things. This is important, because observation, as Krebs puts it, 'is and remains the basis of geography.' To be sure, the activities and forces of human dynamics, in which some would see the essentials of regional unity, are not all amenable to direct observation, but we gain awareness of them by only slightly different means. They are recognized by all regional geographers." Finch (1939, pp. 14–15) This article mentions "forces of human dynamics" that are not amenable to direct observation. It was very challenging in the 1930s to observe not only the forces of human dynamics but also human dynamics themselves due to the lack of tools enabled by technologies to collect such data, especially at a large scale. Traditional interview and survey methods are costly and time-consuming to collect and record human activities and interactions, which in turn present an impediment to applying theoretical frameworks to examining human dynamics at a community or society level. One example is Hägerstrand's time geography, which offers a useful framework for studying human dynamics under various types of constraints in a space-time context (Hägerstrand 1970, 1982). However, the basic concept of space-time path in time geography, which requires data collection of spatial movements over time (i.e., trajectory) for each individual, presents a major challenge to researchers in the era before the Global Positioning System (GPS) technology. Furthermore, even if researchers in the 1970s were able to collect trajectory data of 5000 individuals, it would be a daunting task to show all 5000 space-time paths with pen and paper. Time geography, which has become one of the most widely used conceptual framework in human dynamics research, is very much promoted by the advances of location-aware, mobile, and information and communication technologies during the last few decades that have removed major obstacles of data collection and analysis (Shaw 2012; Shaw et al. 2016). In the meantime, human dynamics research is gaining momentum in geography while geography as a discipline is increasingly recognized by researchers in other disciplines for providing an important perspective to human dynamics research.

Apparently a cogent definition of human dynamics that everybody can sign up for is still elusive due to the diverse disciplines and approaches in the rapidly evolving field of human dynamics research. Instead of defining the boundary of this evolving field, we believe that it is more productive to outline the core elements. The concepts, methods, and applications of human dynamics research are likely to evolve with the changing environments, technologies, and human societies. Research paradigms and dominant research methods employed today will be different down the road. For example, what geographers did 100 years ago are very different from what geographers do today in many aspects. There have been many debates of "what is geography?", yet the field of geography continues to evolve and move forward without a universal definition of the field. Nevertheless, we should not pursue human dynamics research without some directions and guidelines. Below are some of the core elements that should be considered in human dynamics research in our opinion.

- From “physical space” to “virtual space”: With the modern technologies, human activities and interactions have been increasingly taking place in cyberspace, communication space and online social space (e.g., e-shopping, e-commerce, e-education, e-government, email, text messages, online social networks, online games). These activities and interactions in virtual space are not independent from human activities and interactions in physical space. In fact, they interact and influence each other in most cases. It therefore is critical to examine human dynamics in both physical and virtual spaces and their mutual interactions if we want to better understand how human dynamics are evolving and what smart and connected communities should be to better serve future human dynamics needs. Indeed, the on-line and off-line human activities are more closely coupled than ever.
- From “historical” to “real-time”: Understanding changes of human dynamics over time (i.e., historical and long term) is as important as understanding human dynamics at this moment (i.e., real-time and short term). They are for answering different research questions and supporting different policy decisions. Observations of human dynamics at different temporal scales could lead to different findings about human dynamics. We need to examine human dynamics not only at various temporal scales but also the interactions among human dynamics at different temporal scales. The improved granularity of human activities will lead to a better understanding of human dynamics in space and time.
- From “human” to “context”: Human activities take place within a context. Human dynamics research is not just about human. The environments and situations are important factors that influence human behaviors and dynamics. Recent research interests in place and semantics are good examples of deriving meanings behind human dynamics based on the context. There are at least three types of context that need to be considered in studying human dynamics. The first type of context is “what are around us?” which are usually recognized by an individual using relative locations in space (i.e., *relative space*). The second type of context is “what are related to us?” which are usually comprehended by people as relations among different entities (i.e., *relational space*). The third type of context is “what people have in mind” such as motivation, goal, perception, etc. (i.e., *mental space*). All three contexts can involve human and non-human elements. Non-human elements can be entities in the physical space (e.g., a road or a restaurant) or something in the virtual space such as the Google search website. On the other hand, traditional maps and geographic information systems (GIS) are based on absolute locations in space (i.e., *absolute space*). It is important to develop a theoretical framework that can integrate all elements relevant to human dynamics in absolute space, relative space, relational space,

and mental space in order to gain more comprehensive insights on the processes behind human dynamics beyond the observed spatiotemporal patterns.

Obviously, human dynamics is a slippery term that is hard to define its scope with one single definition. This section reviews several different perspectives of human dynamics research and suggests an approach of pursuing human dynamics research by focusing on some important concepts such as space, time, context, process, relationship, and interaction related to human dynamics. Development of a framework that integrates human dynamics in absolute space, relative space, relational space, and mental space can be very helpful to the human dynamics research community with different perspectives across various disciplines.

1.3 Overview of the Chapters in This Volume

This book is organized into 13 chapters. This chapter is written by the editors to provide the context and present an overview of all the chapters in this volume—human dynamics research in smart and connected communities. The subsequent substantive chapters cover various topics related to human dynamics research. This book ends with another chapter by the editors to discuss the limitation of this book as well as outlook and next steps of human dynamics research in the context of smart and connected communities.

Chapter 2 (Thakur et al. 2018) argues that the increasingly available geo-located data sources make it possible to understand human dynamics that previously was not possible. It presents four case studies of using geo-located cellphone data or social media data to improve land use classification, examine population dynamics of a major sport event, investigate transient population dynamics, and assess facility popularity to support its argument. The authors present results of using various methods on different types of data for classifying human population distribution, land use and facility popularity. Despite the data limitations in veracity and completeness, this chapter demonstrates a strong case of using geo-located data to gain insight into human dynamics at a fine resolution.

The research community has used many different types of tracking data to investigate various kinds of human dynamics. One of the common questions is potential biases embedded in each dataset for studying human dynamics. Chapter 3 (Xu et al. 2018) explores this issue based on call detail records (CDR) data and a more complete dataset that includes both CDR data and additional cellphone activities tracked by a cellphone service provider. One key finding of this study is that the number of active cellphone users is a better indicator of the spatiotemporal distribution of cellphone users than the volume of phone calls/text messages. This is consistent with a “burst” human activity pattern identified by Barabási (Barabási 2005); i.e., many human activities exhibit bursts of rapidly occurring activities separated by long periods of inactivity. Use of CDR data to study certain spatiotemporal human activity patterns therefore could be questionable since CDR data reflect where people initiate and/or receive phone calls and text messages rather than where people are distributed. In other words, CDR data could be biased from both spatial and temporal perspectives, especially for those people who use their mobile phones infrequently.

With the increasing human activities and interactions taking place in virtual space, it is critical to be able to represent, analyze and visualize human dynamics in both physical space and virtual space. Chapter 4 (Gao et al. 2018) proposes a spatiotemporal network framework to deliver such functions. It introduces physical edges for movements in physical space, social edges for social relationships and interactions, and physical-social edges to connect physical locations with their associated social activities. This study shows a case study for visualizing such a spatiotemporal network of geo-social interactions with Twitter data, followed by a discussion of four potential quantitative measures of complex interactions in the proposed spatiotemporal network. It is an example of integrating absolute space and relational space discussed in Sect. 1.2 above.

Trajectory data show the locations of moving objects over time that can be useful for studying spatiotemporal movement patterns. However, one major shortcoming of most trajectory data is the lack of semantic data associated with various locations. One popular research topic in recent years therefore is on deriving and managing semantic trajectory data. Chapter 5 (Fan and Stewart 2018) proposes a semantic data modeling framework that employs semantic web technologies to represent, query, reason, and visualize human movements. It builds an ontology-driven knowledgebase to integrate spatial, temporal and semantic data and also presents a use case of student movements on a university campus based on class schedules. This chapter demonstrates some innovative ways of working with semantic data beyond what traditional GIS data models can deliver.

Chapter 6 (Xu 2018) uses cybernetics as a framework to examine synergy between people and technology that transforms each individual and creates cyborgs. Due to increasing mix of activities and interactions in both physical and virtual spaces, this paper chooses Twitter data as an example to illustrate the complexity of cyborg identities. Cyborg, which is a hybrid of part organism and part machine, is used as an overarching identity concept in the Twitter world to help us address the challenge. Cybernetics in this paper helps formalize the relations between cities and their dwellers as communication and feedback loops. Cybernetics therefore can serve as a theoretical foundation to critically examine the technological means for achieving smart cities.

Human dynamics play an important role in many application areas, including many of our public health challenges. Chapter 7 (Wen et al. 2018) proposes a location-based client-server framework, which consists of a client-side smartphone-based risk assessment module and a server-side epidemic simulation model, for assessing personalized exposure to the risk of respiratory disease transmission. This paper represents an application of linking the dynamic movements of an individual to the potential of being exposed to the risks in surrounding environments. By keeping individuals informed about potential risk levels, such an application could influence individual behavioral patterns that reflect important interactions between information flows in virtual space and human movements in physical space.

As individual tracking data at high spatial and temporal resolution levels become increasingly available, privacy protection has been a challenging issue to deal with. With the modern technologies and big-data orientation, individual data are constantly collected by both private firms and government agencies. It is no longer realistic to assume that we have control over our data. It is a matter of who owns what data and how the data are being used. On one hand, the research community is hungry for detailed individual-level data to gain insights on human dynamics. On the other hand, research ethics mandate privacy protection. Chapter 8 (Miller and Hoover 2018) tackles this issue by measuring the uniqueness of locations associated with individual trajectories (i.e., unicity) based on a subset of GPS trajectories from the Microsoft GeoLife dataset. By exploring how unicity varies with the number of randomly selected points, temporal and directional information, and transportation modes, the findings suggest significant privacy concerns due to a high unique level of individual trajectories.

There are an increasing number of studies on the interplay between online social networks and geography to gain insight on the relationships between information flows in virtual space and locations in the real world. Chapter 9 (Koylu 2018) analyzes reciprocal conversations among individuals based on geo-tagged tweets in the U.S. to find out how the semantics of information vary based on the geographic locations and communication ties among the users. This study proposes an approach of using spatial network smoothing and probabilistic topic modeling to extract geo-social semantics that reflect geo-social dynamics of the society.

As the research community is gaining momentum on paying attention to place besides space, Chapter 10 (Cheng and Shen 2018) extends the authors' previous work on "where, when and how long you stay is who you are" to "what place, when and how long you stay is who you are" by shifting from a focus on space-time activity patterns to a focus on place-time activity patterns. This study uses London's police foot patrol tracking data to demonstrate the proposed approach and methods. The results indicate that police who patrolled different locations in London could share a similar place-time activity pattern because different locations are associated with the same semantic meaning. This introduces a new way of measuring similar space-time behavioral patterns.

With an increasing interest in the interactions between virtual space and physical space and a lack of tools for exploring such interactions, Chapter 11 (Ye et al. 2018) presents a Social Network Simulator with functions supporting network generator, network analysis, community detection, and information diffusion modules in an open source package for exploring information diffusion patterns in a social network over time, especially for spatial meme diffusion. This chapter suggests a need of further developing open-source tools to support researchers who study human dynamics that require data management, analysis, and visualization functions beyond what traditional toolkits can offer.

Chapter 12 (Nara et al. 2018) discusses some challenges and opportunities of using social media and big data for human dynamics research. This chapter uses the papers presented in nine paper sessions organized at 2016 and 2017 annual meetings of the American Association of Geographers (AAG) to summarize the data, methods, and applications reported in those papers. The results indicate that a wide range of data, methods and applications have been investigated under the broad human dynamics theme. In addition to seven research challenges that were reported in the literature before, this chapter suggests that frequent changes of the ways that online social media data can be accessed by researchers and data/algorithm uncertainty as two new challenges to human dynamics research.

In the final and concluding chapter (Sui and Shaw 2018), the editors recap the major findings, identify the gaps of the literature, and outline future research directions related to human dynamics in the broader context of smart & connected communities. In particular, the editors emphasize the importance of integrating organic and designed data, crossing the chasm of quantitative and qualitative approaches, and balancing the positive and normative dimensions. Future research on human dynamics in the context of smart & connected community should focus not only on efficiency, but also on equity and sustainability. Last but not the least, the editors challenge the human dynamics research community to embrace the open science paradigm to make all our future research reproducible, replicable, and generalizable. This is the only way to maintain the momentum to make human dynamics research more robust and reliable.

The collection of papers in this volume covers selected topics in human dynamics research, especially from data-driven and analytical perspectives. This orientation reflects the background of the contributing authors whose research interests mainly focus on the analytic aspects of geographic information science and geography. As the first volume in the *Human Dynamics in Smart Cities* book series by Springer, this edited volume serves as a useful reference for the data-driven and analytics side of human dynamics research community. We anticipate additional volumes down the road to cover other perspectives of Human Dynamics in Smart Cities.

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Chapter 2
Utilizing Geo-located Sensors and Social Media for Studying Population Dynamics and Land Classification

Gautam Thakur, Kelly Sims, Huina Mao, Jesse Piburn, Kevin Sparks, Marie Urban, Robert Stewart, Eric Weber and Budhendra Bhaduri

2.1 Introduction

Since the Sumerians started using clay beads to record trade some 7000 years ago to the invention of the tabulating machine in the late 19th Century, our ability to generate data has always, and will continue to, outpace our ability to record and analyze it. This perpetual race sees a continual pattern of breakthroughs in the ability to collect data followed by a period of time when new methods are developed to help make sense of this new source of information. Over the past decade data collection has pulled ahead once again, particularly data on human activity and locations. Thanks in large part from the maturation of mobile sensors and the proliferation of user-generated content like social media, it's estimated that 90% of the data generated since the dawn of civilization has been created in the last two years alone.

With increasing sources of data on human dynamics comes a new ability to understand human dynamics that previously was not possible. Geo-located user generated content from mobile devices allow a level of spatial and temporal granularity that would be prohibitively expensive and time consuming for more traditional methods such as surveys and censuses. The ability to understand where, when, and why humans move across space and time has always been essential to research areas such as urban planning, transportation, population dynamics, and emergency preparedness and response. Geo-located user generated content is allowing new insights into these and many other fields.

Geo-located user generated content can come in several forms. The spatiotemporal GPS locations of cell phones is one form that has demonstrated the ability to shine light on how populations move across and shape the built environment and

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more recently the use of social media on mobile devices has shown tremendous potential to allow us to better understand the distribution of populations at a specific point in space-time. Beyond that, social media data has enabled researchers to understand population activities, events, and underlying cause that generates the dynamics of population movements.

Still challenges remain in our ability to effectively put this data to use. Before one can ask questions of the data we must first collect it and the sheer volume and variety of geo-located user generated content presents a challenge in the gathering, storing, and querying of the data. This majorly occurs because of velocity with data gets generated, validating the data, and the sheer volume of the data. Only once the data is collected, cleaned, and formatted can we begin the next challenge of developing insightful methods that allow us to ask questions we previously were not able to answer.

Four case-studies of using geo-located user generated for human dynamics research are provided. These studies are inspired from the work of Stewart et al. (2017) while initiating a research agenda in human dynamics and land use domain by proposing an explicit model that assists in delineating and articulating the opportunities, challenges, and limitations of using social media. In the first study, mobile phone call volume and GPS locations are used to characterize human activity patterns and provide inference on land use in Dakar, Senegal. Next, we demonstrate the ability of geo-located social media posts to provide insight on population density estimates for special events, such as sporting events or emergency situations. An example of this is presented with college football games on a university campus. Finally, we provide an initial investigation on the potential to identify a specific building's facility use type based solely on geo-located social media content. These studies demonstrate innovative findings that are only made possible because of new forms of data about human activity and their mobility patterns. The chapter underpins the need to utilize new forms of data collection mechanism as well as their use to augment our understanding of human dynamics research and future application of geographical information systems.

2.2 Geo-located Human Activity Data Collection and Management

User generated content with locational metadata is a captivating attribute for modeling population, fine-resolution land use and land cover classification. The spatio-temporal feature, included with potentially descriptive user activity, can provide improved ways of modeling population dynamics at high-resolutions. Additionally, researchers can begin to understand better ways to approach challenges involved in the medical, political, historical, environmental, social, and technological fields (Kuhn 2012). The instantaneous spatial information, much of which is provided by everyday citizens, provides a deeper understanding in how land use topology changes and maintain at different scale and sizes of settlements. This section provides background in the development and current status of geographically focused user-driven content harvested through crowd-sourcing, sensors, and social media.

2.2.1 Neogeography

The evolution from a one-way web browsing experience (e.g. Web 1.0) to now, a two-way interaction and sharing medium is referred to as Web 2.0. Some believe this transformation was so revolutionary in its earliest stages that the term 'Neogeography' was born to encapsulate a new era of geographic practices through web-based operations (Hudson-Smith et al. 2009). One of the most influential instruments to Neogeography was the public release of a free, web-based mapping interface, known as Google Earth. In lieu of expensive cartographic and GIS applications, anyone with access to the Internet could easily upload and share geographic data to make their own maps. This in turn ignited an interest of dynamic mapping to the everyday masses (Turner 2006). Since then, computer scientists have begun constructing other mapping applications and interfaces to produce maps that are less labor intensive and more automated.

2.2.2 Volunteered Geographic Information

Innovations in mobile Internet access (i.e. smartphones) and authority (i.e. non-experts) are redefining how the sciences are adopting non-traditional data. This is a result of the Internet morphing into a modernized power structure of bottom up practices, and what Michael Goodchild termed volunteered geographic information, or VGI (Goodchild 2007). For example, it has become common practice to rely on smartphones to browse the Internet for quick information about a place. And, it is also not uncommon for that data we are searching for to be provided by our peers, rather than established experts. Instead of the traditional construction of knowledge, produced and edited strictly by trained professionals, most anyone with an Internet connection now has the ability to share their local knowledge, and in the case of VGI, with locational attributes. Geographic information disseminated by citizens ultimately becomes a new avenue of information delivery and consumption. Additionally, diverse human contributors can facilitate unique and/or specific geographic knowledge with the simplest post of a tweet (Twitter), status update (Facebook), or picture (both).

2.2.3 Social Media

The enormous popularity of social media suggests that user generated content is here to stay, and potentially, is an acceptable lifestyle of continuous information exchange. With boundless content, users share excerpts of their whereabouts, opinions, beliefs, activities, etc., for the sole purpose of broadcasting one's life to interested parties (Grace et al. 2010; Java et al. 2007). While they may not be intentionally sharing their experiences in hopes of providing data for science, they are nevertheless publicly sharing their activities to socially connect (Croitoru et al. 2012, 2013). Goodchild (2007) has referred to this population as "Citizen Sensors." Their chaotic and unsystematic availability of information proves worthwhile for application program interfaces (APIs) which can pragmatically mine user generated content (e.g. Tweets, Check-ins) to give a quantitative look into the world around us. This chaotic and unsystematic availability of user information is what has provoked a relationship between scientists and Big Data.

2.2.3.1 Twitter

As of October 2016, at least 550 million tweets were sent per day from the 100 million daily active users (Twitter IPO filing). With this plethora of streaming information from certainly one of the industry's leaders, Twitter is an ideal platform source to harvest media feeds from through its API. On the company's website, their policy states that in exchange for using their services, the user agrees to have their information made public and searchable by third parties, as long as the user's account privacy settings are set accordingly (Twitter Privacy Policy). This agreement is what allows this research to explore Twitter's 140-character messages to better understand actual, first-hand experiences during a live event. Additionally, the fact that more than three-quarters of active users socially connect through a mobile device only further supports the possibilities of gaining up-to-date access with location accuracy (Twitter IPO filing). However, social media users are a sample of the general public since not everyone participates. Nevertheless, any amount of publicly shared experiences or actions, recorded in the moment through smartphones, especially those with locational tracking services activated, can ideally illustrate a more accurate depiction of population dynamics.

2.2.3.2 Facebook

In its origin in 2004, Facebook was only accessible to college students from a few selected universities. Today, Facebook connects individuals (13 years of age or older), all across the world with 1.13 billion daily active users.[1] While Facebook

[1]http://newsroom.fb.com/company-info/. Retrieved: September 14, 2016.