My research focuses on developing techniques to **analyze online behaviors to improve individual well-being and address societal problems** using online data. The unprecedented increase in social media use brings many opportunities and threats at the same time. Social media help people to connect and share their opinions and experiences with millions of others. We can consider social media as a microscope for an online world which magnifies individual and group behaviors. In my research, I leverage online and offline data to gain insight on human behaviors, analyze technological systems to mitigate threats against online conversations by developing techniques in **machine learning**, **network science**, and **computational social sciences**.

Information spreading on social media contributes substantially to shaping collective opinions. Most information campaigns can be benign, but some may be designed for terrorist propaganda, political astroturf, and manipulation of financial markets and individual emotional states. The detection of viral memes that are sustained by coordinated campaigns has critical social implications and poses numerous technical challenges; so does the identification of campaigns that might reach critical popularity in the future. My dissertation work focused on the detection of persuasion campaigns and social bots using the tools of machine learning, data mining, and network analysis. I focused on three problems to study online discourse and its manipulation: (i) analysis of information diffusion and **characterizations of user roles** during online discourse; (ii) how to **identify orchestrated campaigns** on social media from grassroots discussions; (iii) how to **detect social bots** and analyze interaction between different entities in the Twitter ecosystem.

Today billions of people share their experiences, ask for a recommendation, and engage with others online. My research on socio-technological systems bring opportunities to study cultural patterns, dynamics of emotions, and collective phenomena. Information collected through various services and devices tell **stories in macro- and micro-scale**. Macro-stories capture dynamics of cultures, social norms, and influence of real-world events. Similarly, micro-stories describe events occurred within a shorter timescale; visiting a city, reading a story, or merely experiencing an emotion. I am interested in analyzing the behaviors of individuals in various scales to learn the consequences of their actions and model processes effecting their health and well-being. I studied the **causal impact of our actions** on online trajectories and worked on investigating **how we experience emotions** to capture human behavior more in detail.

Throughout my research, I always keep "curiosity" as the first principle to identify exciting research questions. I want to answer both timely and important issues for society as well as bold questions on understanding the nature of our behaviors.

Predicting and Mitigating Online Threats

Nowadays the Internet provides immediate reach to information, and we enjoy access to a vast amount of knowledge and an ability to communicate without borders. However malicious actors work toward abusing online systems to disseminate disinformation, disrupt communication, and manipulate individuals, with automated tools such as social bots. Using social media as a tool, I study online protests, political debates, and how people create, share, and consume information.

During my Ph.D., I built systems that analyze social media data and extracts network, temporal, content, and user-based features to detect online campaigns. I developed several modules for this framework: (i) a clustering procedure that uses metadata to compute the similarity between memes [C2, J2]; (ii) a classification system that determines whether a meme is potentially an orchestrated campaign or a genuine, grassroots conversation [J7, C8]; (iii) a social bot detection framework described more in detail below.

Increasing evidence suggests that autonomous entities known as social bots generate a growing amount of social media content. While not all bots are harmful, there is an ever-increasing record of malicious applications of social bots [J5, J8, J11]. To detect social bots, I built a machine learning system, called **Botometer**,[1] that extracts more than a thousand features in six different classes:

[1] Botometer: botometer.iuni.iu.edu

users and friends meta-data, tweet content and sentiment, network patterns, and activity time series [C13]. I trained my models on publicly available datasets of social bots and evaluated them with a manually curated dataset of active users. The resulting system performs with high accuracy in detecting both real users and different classes of social bots. Using this classification framework, I analyzed over 14 million active users on Twitter to characterize communication between separate entities and estimated that 9%-15% of accounts on the Twitter ecosystem are indeed social bots [C13]. After the investigation for the integrity of US presidential elections, Twitter starts deleting or suspending approximately 17,000 accounts with suspicious activities daily. These numbers align with our earlier estimates.[2]

Botometer had served over 250M requests so far, and it receives over 100k queries daily through our API and website [C13, C6]. Leveraging the lessons learned from this project, our team at Indiana University participated to the DARPA bot detection challenge. We identified all bot accounts as the second fastest and the third most accurate team [J3]. We have been studying how bots were employed to spread low-quality information during the 2016 US Presidential election to point their crucial role in the political system [J9]. Similarly, I investigated journalists on Twitter and their follower networks for the involvement of bots and demonstrate anomalous patterns of followers and perplexing relation between popularity and bot engagement for verified and non-verified accounts [J13].

Analyzing Information Diffusion and Online Discourse

Online social networks have an impact on online discourse on politics and consequences for the offline world. My research on online discourse explores information diffusion and censorship under geographical constraints. I analyzed trending topics on Twitter and how they compete for popularity at the local level to emerge as winners at the country level. I identified two distinct mechanisms governing diffusion: those that surface locally, coinciding with three different geographic clusters; and those that emerge globally from several metropolitan areas, coinciding with major air traffic hubs [C3].

Additionally, I analyzed the social upheaval occurred in Turkey in 2014. My analysis first characterized the spatiotemporal nature of the conversation about Gezi Park demonstrations, showing that similarity in trends of discussions mirrors geographic cues. More importantly, I studied the characteristics of the users involved in this conversation and what roles they played and how roles and individual influence evolved during the upheaval. My analysis revealed that the discussions become more democratic as events unfolded, with a redistribution of influence over time in the user population. By observing how the online and offline worlds are tightly intertwined, I showed that exogenous events, such as political speeches or police actions, affect social media conversations and trigger changes in individual behavior such as changing screen name as a way to reveal their opinions [C5, J6].

During my two summer internships at Microsoft Research, I was fortunate to explore different topics on modeling heterogenous intents of users on information diffusion [C9] and analysis of social media timelines to study individual experiences and their outcomes [C12]. Heterogeneous intents of users are investigated to study how users adapt their language to align with their audience to optimize information diffusion and maximize their influence. In my second summer, I analyzed search query logs to identify experiential questions people ask, and I contributed to building a causal analysis system to answer those questions by mining social media timelines to provide people better decision-making support and predict the outcomes of their actions [C12].

Modeling Individual Performance and Well-being

My ongoing research activities focus on modeling user interactions, leveraging online data across multiple platforms to understand conscious and unconscious behaviors. My prior work in social bots can aid in this endeavor. However, users and automated accounts use social media differently. Social bot accounts follow simple instructions to increase visibility, spread content, or influence others. Humans have more complex patterns of interactions, the creation of content, and information consumption. Properties such as sentiment of conversations or interactions with friends follow unique but observable patterns. Users with similar motives share similar temporal signatures of their behaviors. But users

[2] Twitter Blog: An update on our elections integrity work

may have multiple motives leading to different behaviors. The identification of distinct patterns of behavior is crucial to the study of the social system at the level of users.

Our behavior is shaped by a complex mixture of emotions, belief systems, and biological rhythms and constraints. Identification of internal processes is an interesting challenge since we can learn more about our unconscious mind and mood. We can study these minute-scale effects on an aggregated level over populations. Recently, I investigated how explicitly stating our emotions effects the mood in a longer time scale and quantified the development of mood before and after one vent their emotions online [J10].

In another project, I have been studying the relationship between performance and online success. I analyzed changes in influence, popularity, and productivity of accounts over a period on user timelines. I also analyze account trajectories using a stochastic model to uncouple the effects of popularity and productivity from individual qualities quantified as social impact factor for each account. I introduced a metric, called Q_T-factor, that captures a Twitter user's ability to compose messages that engages its audience. This metric is quantifying real engagement and is independent from the number followers a user has and predictive of the future success of an account. I developed an online platform to demonstrate our research.[3] My findings argue against the calcified interpretations about popularity and engagement by presenting sublinear scaling between those entities and demonstrating universal patterns across different social systems.

Research Agenda

I am excited about the opportunities to **mine social signals to gain new insights into human behavior and society**. The world we have been experiencing is changing, and we have data with higher temporal resolution, more accurate as well as reflecting a complete picture of individual lives. The ethical collection of multi-modal data about individuals will be instrumental in understanding human behaviors. I want to be one of the pioneers in this area by developing new models and tools to study complexity regarding analyzing the behaviors of individuals.

My long-term research goal is to develop models that describe the intents and actions of individuals and groups. Detecting strategies employed by users is crucial for many reasons: preventing terrorist recruitment, identifying different classes of sophisticated social bots, and detecting orchestrated campaigns. Deviations from the regular patterns can also point to important events and pre-cursors of significant transitions. Understanding change in behavior helps to study mood changes and to identify life events. In the following, I describe two main research directions on mitigating online threads and modeling human behaviors that I am excited to pursue.

Detecting strategies and orchestrated activities of malicious accounts.

Intents and strategies of malicious entities such as social bots and orchestrated campaigns are either fully automated by software or directed by motivated human agents. Armies of social bots and misinformation campaigns are executed to promote ideas, advertise products, or sway public opinion. We have been observing social bots that attempt to persuade, influence, and deceive. My experience in the identification of social bots and early detection of campaigns helps to isolate those activities and study their strategies in-depth. I am interested in building detection systems that are evolving to lead in this arms-race by exploring behavioral signatures of users and characterizing their strategy, as well as, monitoring online communities for early identification of new threats.

Recent advancement in deep learning technologies brings opportunities to learn from a vast amount of social media data. However, the same techniques can be used to create more sophisticated bots by employing generative adversarial networks (GANs) for creating novel human profile pictures that cannot be discovered by reverse image search online, using language models achieving near-human performance on comprehension, or controlling account behavior through reinforcement learning to simulate more organic interactions.

Approaches focusing on each account as an independent agent still captures information on automated behavior; however, orchestrated activities of groups of agents pose mischievous treats. To

[3] Q-Factor: qfactor.app

address this challenge, I have been working on developing novel approaches to extract behavioral information and signatures of coordinations. Applications of latent space representation are essential to capture trajectories of user behaviors and their corresponding behavioral clusters. I am building those representations for population-level analysis of temporal datasets to track orchestrated activities on online discourse. I also aim to use representations learned from online data to simulate and test intervention strategies on social systems. Another exciting dimensions of this research is addressing problems of transparency and accountability of detection algorithms, since they have been utilized in various domains. I have been developing novel models to efficiently learn pairwise comparison relations for building fair and explainable models [U3].

My research on prevalence of social bots helped policy makers to address automation online.[4] I am currently investigating roles of different actors and their interactions in this complex system such as users, politicians, journalists, and corporations.

Modeling individual behaviors and studying human nature.

The brain is a mysterious organ that processes a vast amount of information surrounding us and controls essential biological processes such as regulating heart rate, temperature, and mood. Deviations from the stable patterns manifest itself as a mental health disorder or early symptoms of a disease. Sleep is one of the most essential and also the most neglected contributor to our well-being. I am currently investigating major biological and environmental information to quantify the role of sleep for our well-being. I am using digital fingerprints to model individual sleep habits along with information collected through social media to estimate mood and sensory information like heart-rate and exercise collected through quantified-self devices. I am especially interested in an individual analysis to characterize differences within the population and how certain groups react to different conditions.

The intertwined ecosystem of mobile applications provides opportunities to combine data collected in different platforms. Collaborating with industry partners and medical schools, I want to analyze the multi-model data of human behavior information to find novel associations between sleep, performance, and preferences such as music and food. One of the applications of ego-centric network research is to model mental health problems. In this domain, I would like to infer whether a user has issues like bipolar disorder or depression based on prior online interactions. My goal is to build models of interconnected data sources to highlight the relationships between user attributes and behavioral features. Once a particular group of people is selected on one platform, users with similar characteristics can be identified on other platforms. Additional features about the group can be extracted from these platforms to improve the inference model for predicting, simulating, and intervening on user behaviors. My goal of this research is to formulate new hypotheses about disease progression and to develop mechanisms for support.

In consciousness, the most cryptic transition occurs between wakefulness and sleep states, which can transform our understanding of performance, well-being, and health. Drug-induced states are also vital in treating mental health disorders and designing lifestyle changes for prevention and improvement in health outcomes. Unorthodox approaches that combine observational data from online fingerprints and experimental data from the controlled environment are required to study altered states. Collections of information about mobility, diet, and exercise along with content we are exposed to are vastly available within the interwind ecosystems of applications and devices. I want to study various altered states using digital traces of individual lives along with the collaborations conducted in experimental and computational disciplines. Clinical studies can validate a hypothesis created by monitoring digital signatures and yield actionable recommendations to critical societal problems like improving well-being and health outcomes.

Conference proceedings [C], journal articles [J], and publications currently under review [U] referenced in this letter corresponds to the academic work on my resume.

[4] CA legislature information: https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB1001