

Bot Human Nexus on Social Media

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Thesis Proposal

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The CMU center for Informed DEMocracy And Social cyber-security



Carnegie Mellon University

Purpose & Scope

- Examine the bot and human ecosystem on social media platforms in terms of social and computational aspects
- Make sense of massive human communication patterns and interception of automated bot interactions



Westworld, HBO: Examining Artificial Life

Overall Questions

- How do bots and humans co-exist in the social media landscape?
- Are there different types of bots in social media and what are their unique characteristics?
- Do bots engage in activities complementary/different to humans?



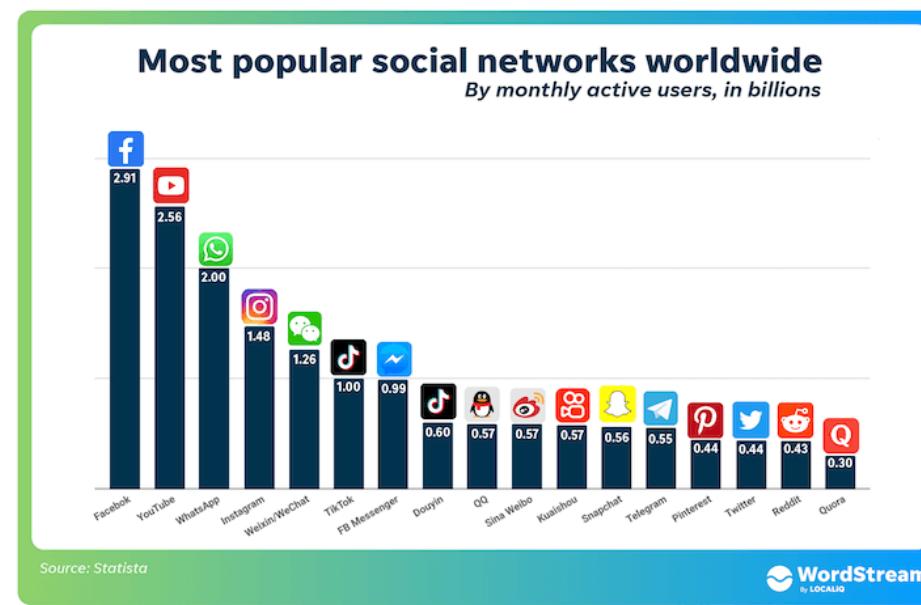
Westworld, HBO: Examining Artificial Life

What is a Social Media Platform?

An Internet-based application for social networking

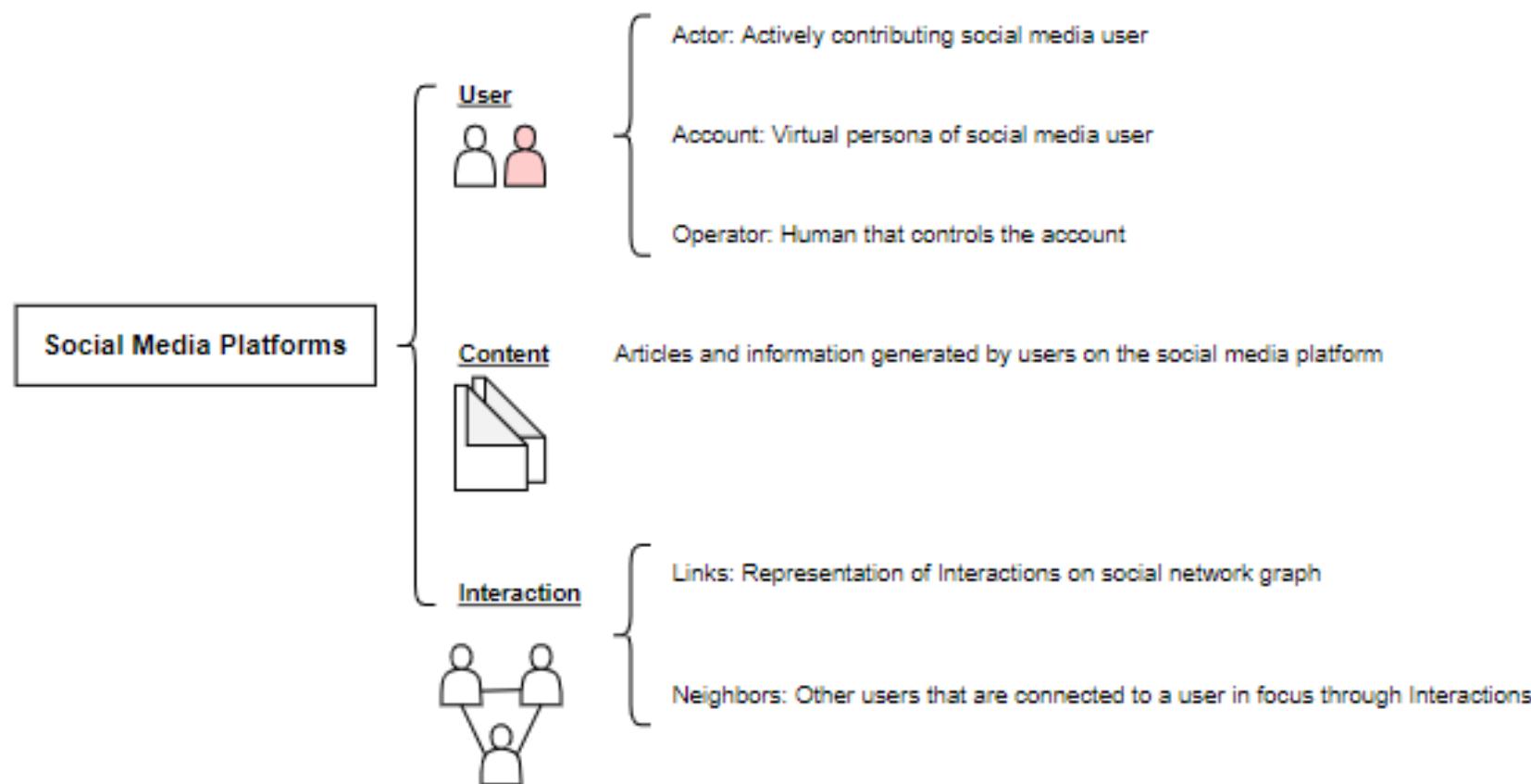
User-Generated Content

Making Connections with other people



Structure of a Social Media Platform

- **Users** create/distribute **Content** and form **Interactions** with each other

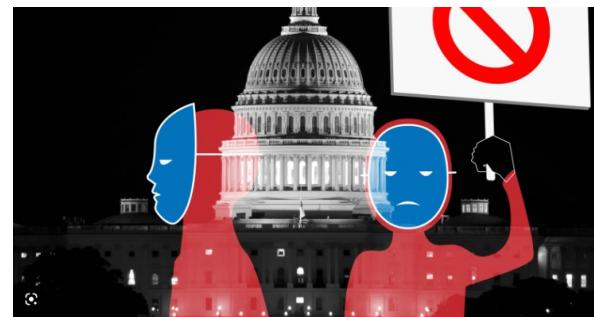


Bots on Social Media Platforms

- Social Media Bot, or Bot: Programmable account that automatically carries out a series of mechanics on platforms



Bots affect businesses



Bots affect elections

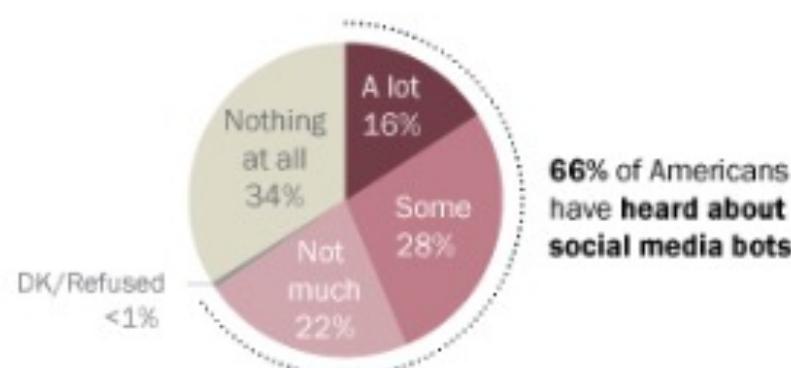


Bots affect entertainment

A large proportion of people believe bots are used maliciously

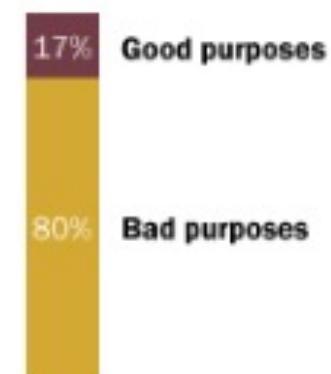
About two-thirds of Americans have heard about social media bots, most of whom believe they are used maliciously

*% of U.S. adults who have heard
about social media bots*



66% of Americans have heard about social media bots

Of those 66% who have heard about social media bots, % who say bots are mostly used for ...



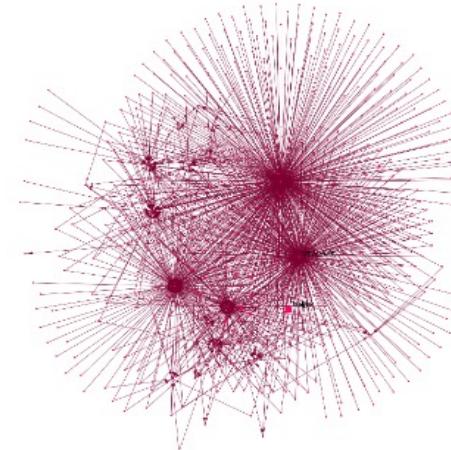
Source: Survey conducted July 30 - Aug. 12, 2018.

Pew Research Center

In reality, Bots are used for a variety of purposes, Good & Benign too



Chat Bots



Amplifier Bots



Announcer Bots

Bots that go BONG

etc



Social Media Bot-Human Nexus

1. Ecosystem: Bots vs Humans

Can we systematically and efficiently differentiate a bot and human account?

What are the similarities & differences between Bots and Humans?

2. Habitat: Types of Bots

What is the habitat that bots live in?

What are the characteristics of different types of Bots?

3. Community: Coordinated Bots

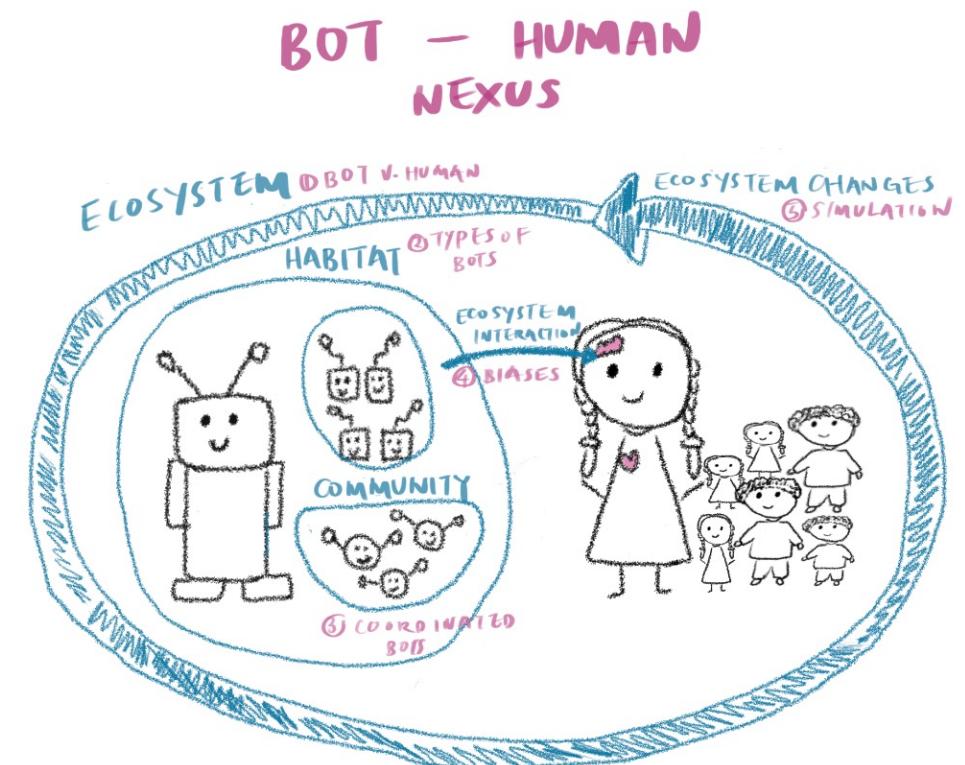
How do Bots coordinate with each other to increase influence?

4. Ecosystem Interaction: Biases

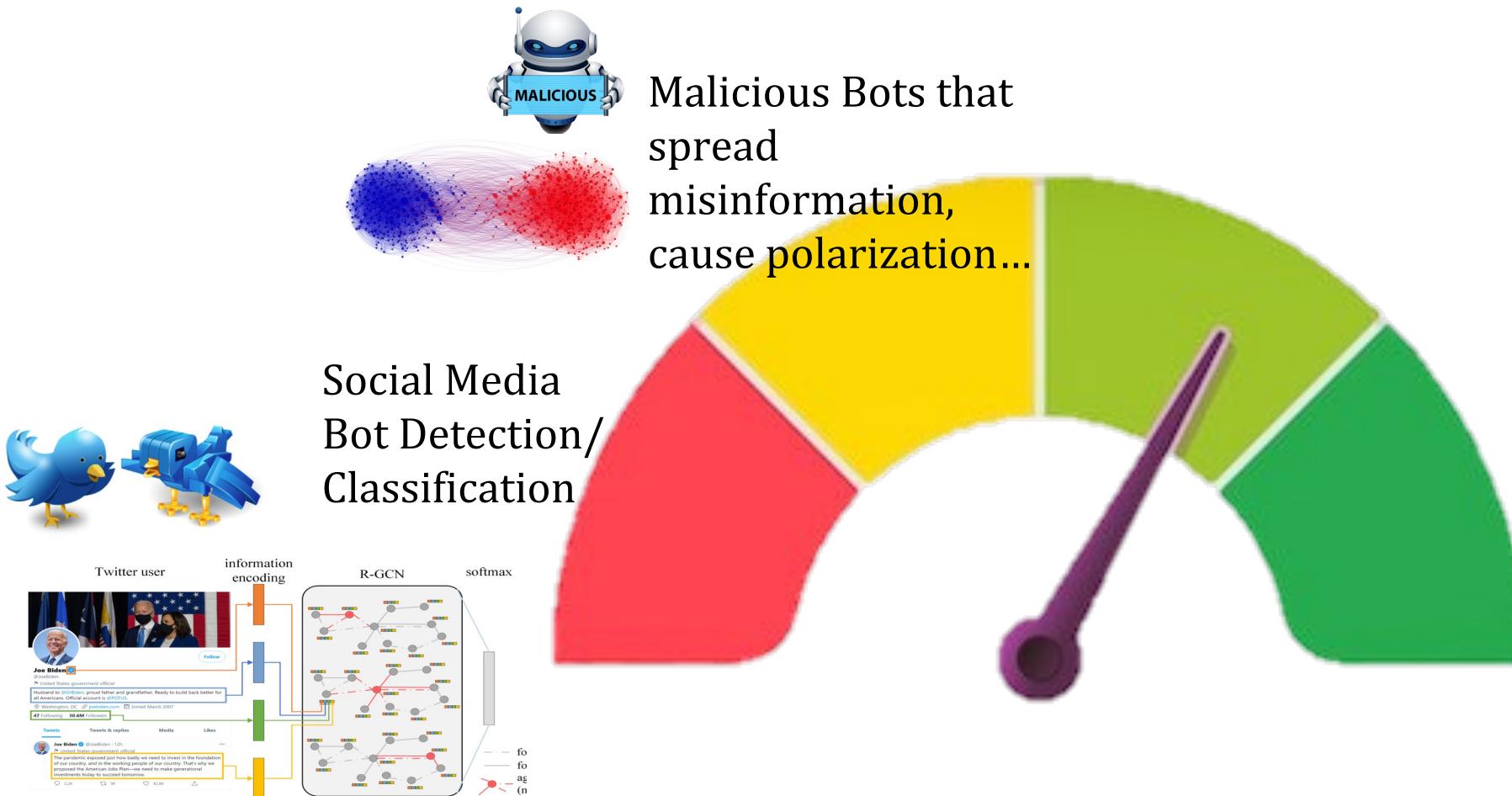
What are the human structural, cognitive, and social-cognitive biases that Bots target?

5. Ecosystem Changes: Simulation as a test bed

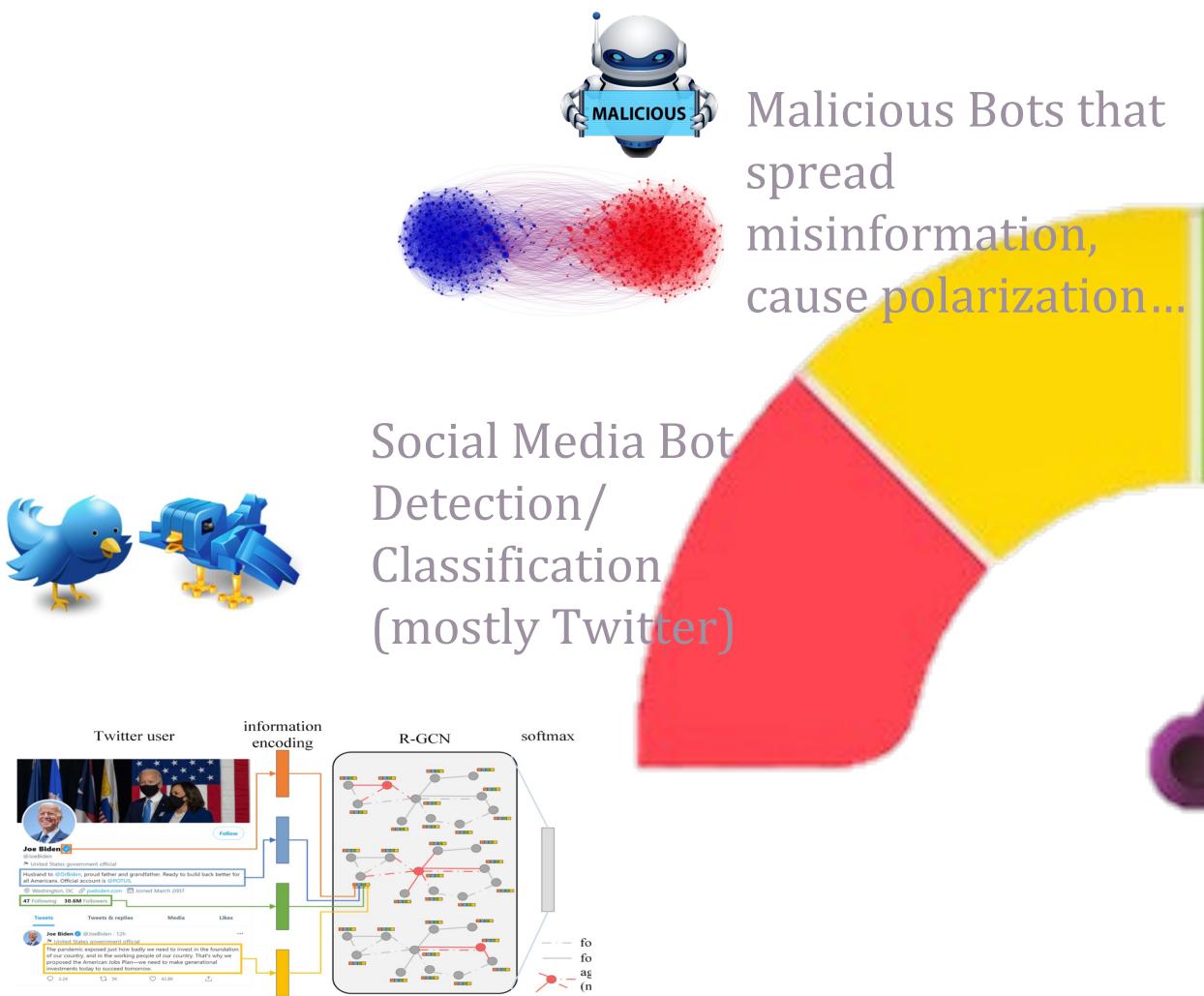
How much pressure from Bots is required to change the ecosystem?



Moving the Needle on Social Media Bots

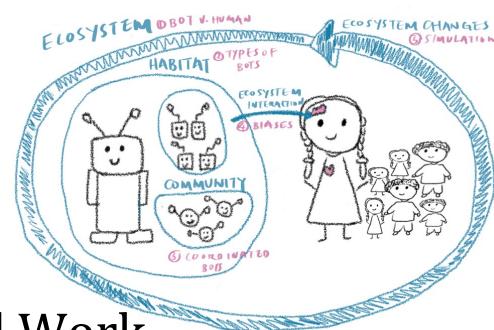


Moving the Needle on Social Media Bots



Completed Work

Bots and Humans coexist because there is a continuum of goodness of bots & different types of bots; multi-platform



Proposed Work

Interplay of bots on human biases; projecting social media interactions through simulation



Data

* Dataset collected from repository
^ Dataset self-collected

4 social media platforms,
> 200million social media accounts,
> 5billion social media posts

	Dataset Name	Details	Ch 1	Ch 2	Ch 3	Ch 4	Ch 5
Twitter	OSOME Bot Dataset *^	Users: 86k, Posts: 3.4mil	✓				
	2018 Black Panther Movie *	Users: 1.6mil, Posts: 17.7mil	✓	✓	✓		
	Asian Elections *	Users: 951k, Posts: 4.1mil	✓	✓			
	2019 Canadian Elections *	Users: 1.9mil, Posts: 18mil	✓	✓			
	2019-2020 US Elections *	Users: 1.6mil, Posts: 55mil	✓	✓	✓	✓	
	2020-2021 Coronavirus *^	Users: 208mil, Posts: 4.2mil	✓	✓	✓	✓	✓
	2020 ReOpen America *	Users: 201k, Posts: 4.4mil	✓	✓	✓		
	2021/2023 French Protests *^	Users: 343k, Posts: 644k			✓		
	2023 Chinese Balloon ^	Users: 121k, Posts: 1.2mil		✓		✓	
Reddit	2022 Reddit ^	Users: 667, Posts: 13k	✓	✓			
Instagram	2022 Instagram ^	Users: 1935	✓	✓			
Facebook	2022 US Elections *				✓		

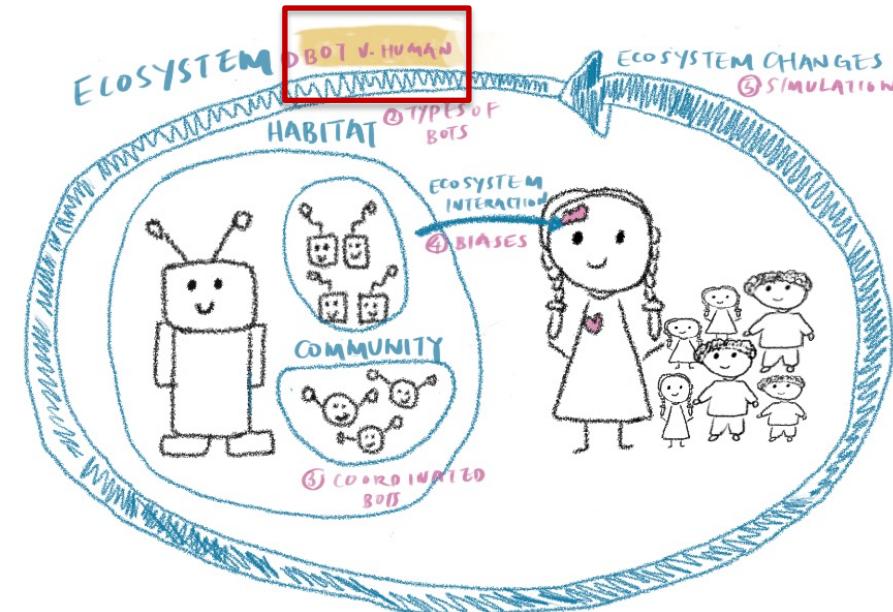


List of Tools Developed

Tool	Function	Ch 1	Ch 2	Ch 3	Ch 4	Ch 5
BotBuster	Bot Detection by Classification (neural network-based, GPU)	✓				
BotBuster For Everyone	Bot Detection by Classification (fast, CPU-based)	✓				
News bot detection	Detection of bots that post news		✓			
Amplifier bot detection	Detection of bots that amplify information		✓			
Cyborg Hunter	Detection of agents that are sometimes-bots, sometimes-human		✓			
Repeater Bot Hunter	Detection of bots that repeatedly post messages		✓			
Type-Of-Bot Sorter tool (<i>in progress</i>)	All-in-one types of bot detection tool		✓			
Synchronized Action Framework/ Coordinating Narratives Framework/ Similar Images Framework	Detection of Synchronization through temporal/ narrative/ image means			✓		
Combined Synchronized Index	Identification and ranking of synchronized users			✓		
Bot Simulation Tool (<i>planned</i>)	Detection of changes in a variable as social network changes due to bot activity across time					✓

Ch 1: Ecosystem/ *Bots vs Humans* Guiding Questions

- Can we systematically and efficiently differentiate a bot account from a human account?
 - Bot Detection Classifier: Multi-platform, Mixture of Experts model
- What are the similarities and differences between Bots and Humans?
 - Temporal, linguistic, network aspects



Ch 1: Ecosystem/ *Bots vs Humans*

Completed Work

- Can we systematically and efficiently differentiate a bot and human account?**
- Bots are detected through bot detection classifiers, which are trained from manually annotated datasets
- Limitations of current classifiers:
 - Take in all account features to perform prediction in one go; does not cater for incomplete data collection; smaller feature set; difficulty of collecting data (rate limits)
 - Usually single platforms, and mostly built for the Twitter platform
 - Requires a threshold for the returned bot probability score (If the bot probability score is above a defined threshold, the account is deemed as a bot; otherwise as a human): but what value?

Ch 1: Ecosystem/ *Bots vs Humans* *Completed Work*

- ❑ Bot detection threshold values²:
 - ❑ Systematic large-scale analysis (users, posts) of bot classification scores and their changes across different number of posts and number of days
- ❑ BotBuster: A Multi-Platform Bot Detector using a Mixture of Experts Concept¹
 - ❑ Incomplete input data: each data type (username, post text...) handled by a separate expert, trained specially on the corresponding data, aggregated to provide a final bot prediction
 - ❑ To handle multiple platforms: collected data, trained and tested on Twitter, Facebook, Instagram; harmonized the naming conventions of platforms and evaluated the similarity of accounts across platforms

¹ Ng, L. H. X., & Carley, K. M. (2023, June). Botbuster: Multi-platform bot detection using a mixture of experts. In Proceedings of the International AAAI Conference on Web and Social Media (Vol. 17, pp. 686-697). Chicago

² Ng, L. H. X., Robertson, D. C., & Carley, K. M. (2022). Stabilizing a supervised bot detection algorithm: How much data is needed for consistent predictions?. *Online Social Networks and Media*, 28, 100198.

Manual Bot/Human Annotation

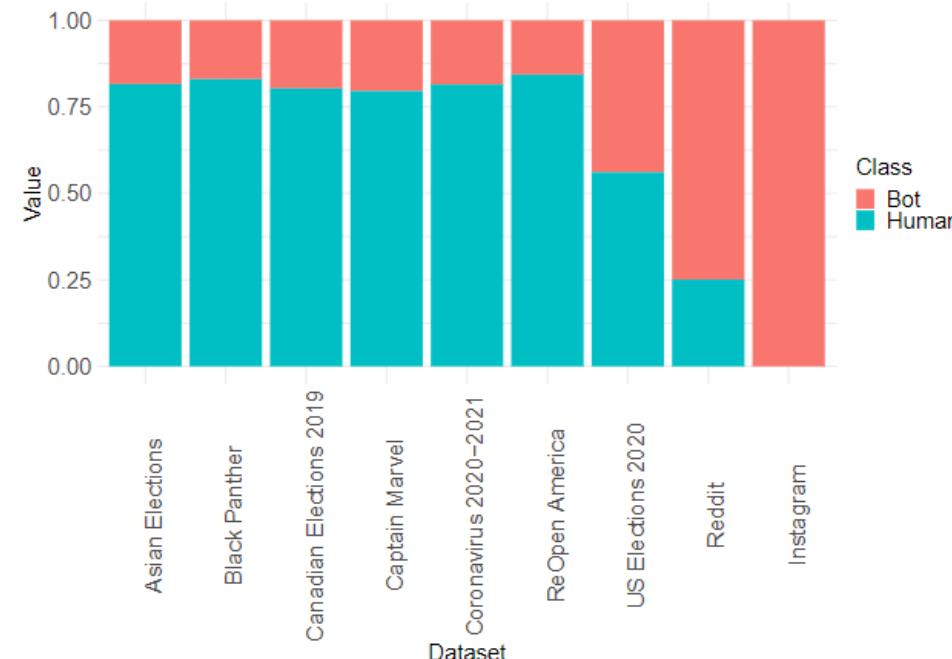
- ~2767 to ~3000 data points extracted for each Twitter/ Reddit dataset
 - Equal proportions of bots/humans
- Better at detecting not-bots

True Negatives	61.4%
False Positives	13.3%
False Negatives	12.3%
True Positives	13.0%

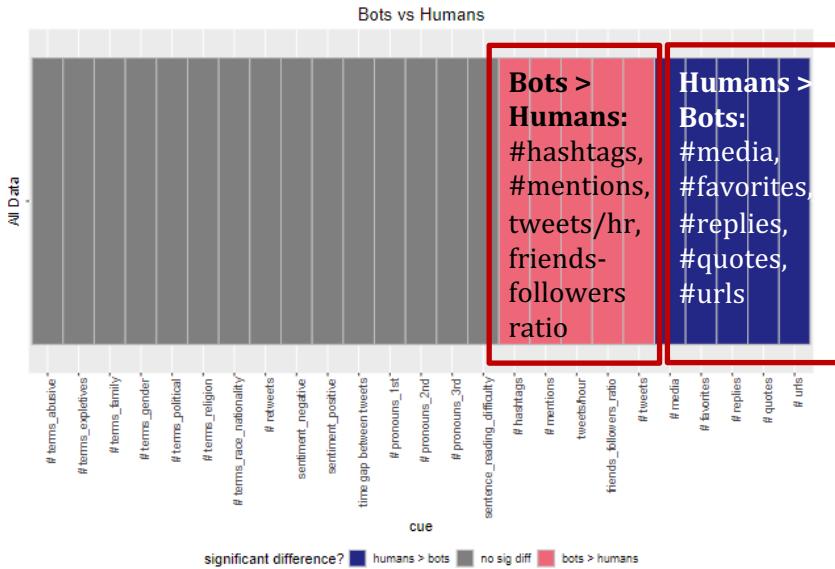
Ch 1: Ecosystem/ *Bots vs Humans*

Completed Work

- What are the similarities & differences between bots and humans?**
- Ran the massive datasets through bot detection algorithms
- On average, ~20% of the datasets are classified as bots
 - Reddit/ Instagram have higher percentage due to the collection strategy

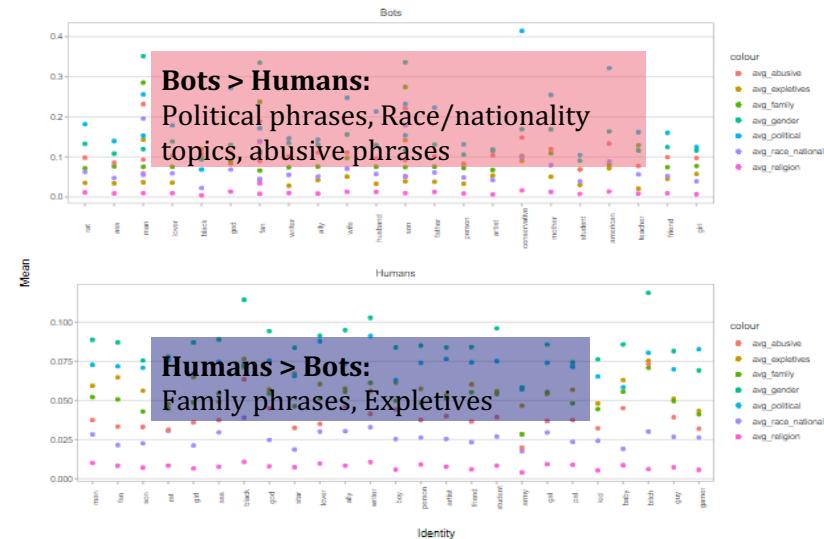


Ch 1: Ecosystem/ *Bots vs Humans* Completed Work



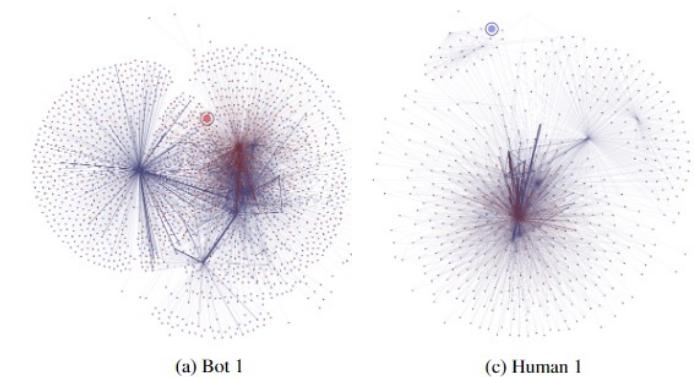
Linguistic Cues Comparison with ANOVA

Bots and Humans use different sets of linguistic cues



Topics, Emotional values Comparison with t-tests

Bots and Humans present themselves on social media with different sets of identities and emotional values



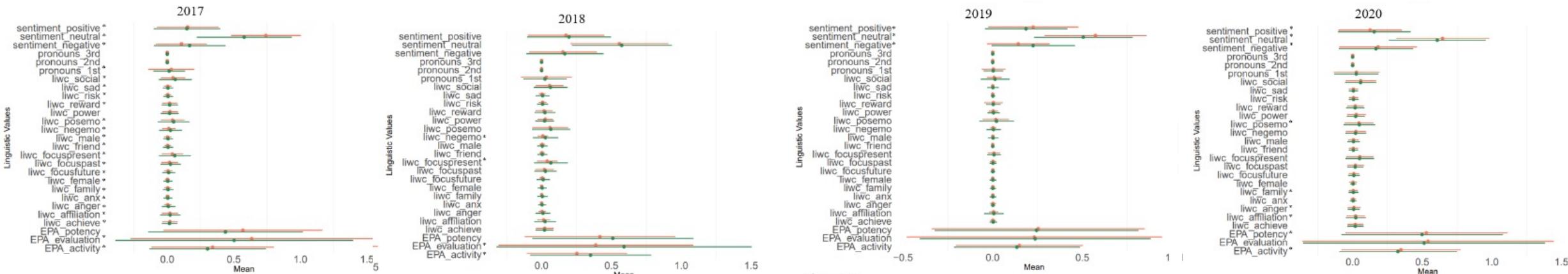
Communication structure with network analysis

Bots: flower-burst communication network structure
Humans: hierachal structure



Ch 1: Ecosystem/ *Bots vs Humans* Completed Work

- Bot/human differences evolve across time
 - Linguistic differences are less pronounced over the years, harder to differentiate



2017
Avg difference =
 0.024 ± 0.045

2018
Avg difference =
 0.02 ± 0.04

2019
Avg difference =
 0.009 ± 0.02

2020
Avg difference =
 0.006 ± 0.011

Ch 1: Ecosystem / Bots vs Humans

Proposed Work

- Collecting data of equal proportions of bots and humans
- Refreshing the datasets to keep up to the latest social media users
- Deeper statistical analysis of comparison between bots/humans analysis
- Deeper analysis of the differences in behavior between bots/humans in key events (e.g. coronavirus, elections)

Ch 1: Ecosystem/ *Bots vs Humans* Contributions

- ❑ Development of bot detection by classification model
- ❑ Systematic statistical evaluation of bot detection models for setting threshold values
- ❑ Analyze the differences between bots and humans in terms of linguistic cues, identities and social interactions across 5 billion social media posts
- ❑ Provide a deeper analysis of the differences in behavior between bots/humans in key events (e.g. coronavirus, elections)

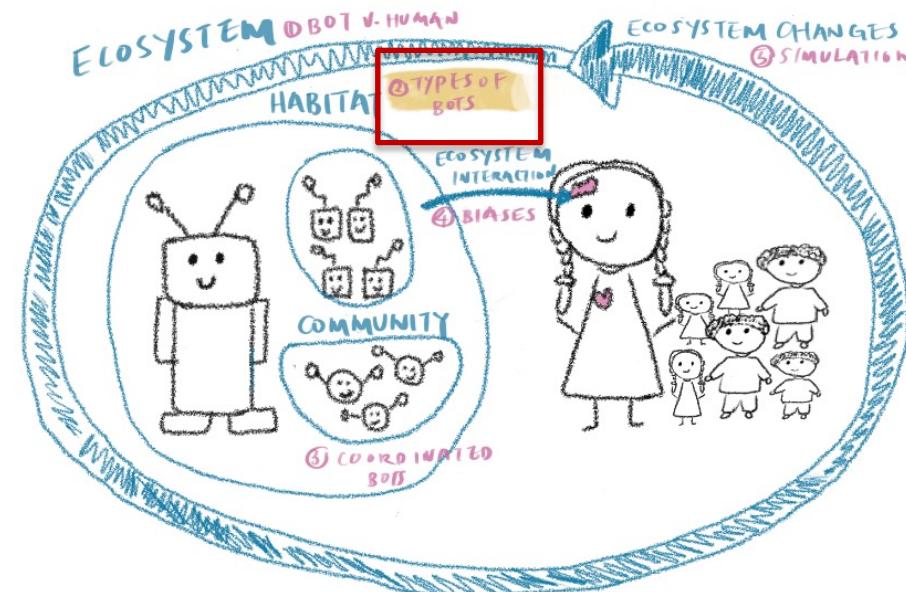
- ❑ Publications:
 - ❑ *Stabilizing a supervised bot detection algorithm: How much data is needed for consistent predictions?* Online Social Networks and Media, 2022
 - ❑ *Botbuster: Multi-platform bot detection using a mixture of experts.* ICWSM, 2023
 - ❑ *Bot-based emotion behavior differences in images during kashmir black day event.* SBP-BRIMS, 2021
 - ❑ *Popping the hood on Chinese balloons: Examining the discourse between US and China-geotagged accounts.* First Monday, 2023

- ❑ Planned Publications: The Big Book of Bots

Ch 2: Habitat / *Types of Bots*

Guiding Questions

- What are the types of bots that live in the social media space?
- What is the habitat that different types of bots live in?
 - What types of bots are associated with which non-bot users?
 - What are their network interactions like?
- What are the characteristics of different types of bots?



Ch 2: Habitat / Types of Bots Completed Work

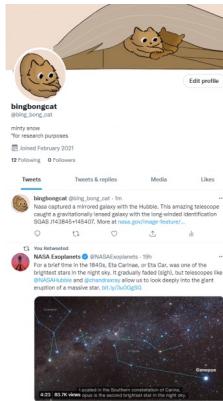
❑ What are the types of bots that live in the social media space?

1. Self-Declared Bots
2. Common Bots
3. Cyborgs
4. News Bots
5. Announcer Bots
6. Amplifier Bots
7. Repeater Bots
8. Bridging Bots
9. Content Generation Bots
10. Cross Platform Bots
11. Multi Type Bots
12. Other Bots

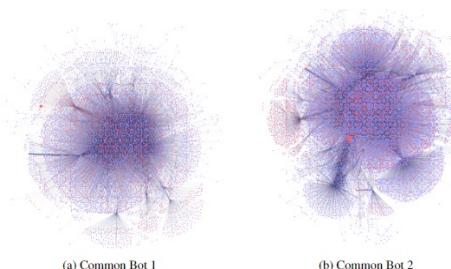
Self Declared Bots: Contain the word “bot” in user information



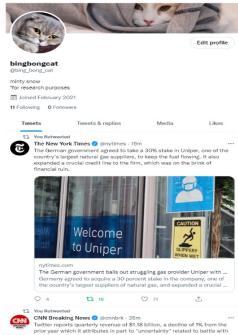
Cyborgs: Human with automation or bot with human input



Common Bots: More than one bot algorithm identify user as bot



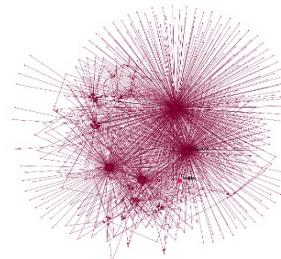
News Bots: Serve original news or aggregated news feed



Announcer Bots: Serve announcements periodically or by a trigger



Amplifier Bots: Boost narrative themes, influence of other accounts, overload others with content



Type of Bot	Definition	Methodology for Detection	Usages
Self-Declared Bot	<ul style="list-style-type: none"> Users that outwardly declare themselves as bots 	Parse metadata of user account to identify the term "bot"	<ul style="list-style-type: none"> Pull data from websites (e.g. weather, moon phases) Announcements (e.g. health directives)
Cyborgs	<ul style="list-style-type: none"> Accounts that exhibit both human and bot-like activity 	Frequent changes of bot classification with high bot probability change	<ul style="list-style-type: none"> Used by politicians, CEOs, activists etc to provide periodic announcements and personal touch Mix up account behavior to prevent suspensions
News Bots	<ul style="list-style-type: none"> Automated accounts that post news updates 	<ul style="list-style-type: none"> - Parse metadata of user account to identify the term "news" - Identify if post is news headline or not with self-constructed model; bot if majority of posts are news headlines 	<ul style="list-style-type: none"> Originate news (e.g. news channels) Aggregate news Provide news to oneself Disseminate (fake) news
Announcer Bots	<ul style="list-style-type: none"> Automated accounts that announce certain information 	Periodic posting patterns through FFT techniques	<ul style="list-style-type: none"> Trigger-based bots for alerts (e.g. price drops) Content Moderation (e.g. subreddit threads) Periodic announcement to disseminate news
Amplifier Bots	<ul style="list-style-type: none"> Bots that programmatically boost narrative themes and manufacture support 	Central users of share/retweet/mention network	<ul style="list-style-type: none"> Buy influence for own account Create and maintain influence for accounts of leaders Amplify content with specific narratives Amplify influence of specific user or groups of users
Repeater Bots	<ul style="list-style-type: none"> Bots that excessively repeat posts and keep bulk of the content the same 	Frequent posts of similar sentences, identified through post vector similarity comparison	<ul style="list-style-type: none"> Personal reminders Promotions, advertisements, propaganda
Bridging Bots	<ul style="list-style-type: none"> Bots that connect groups together 	Users that communicate between two Louvain clusters in an all-communication network	<ul style="list-style-type: none"> Connect groups of users to take notice of their narratives
Content Generation Bots	<ul style="list-style-type: none"> Automated users that create content for the online ecosystem 	Large proportion of original content compared to shared content	<ul style="list-style-type: none"> Integration bots to connect multiple platforms with personal accounts Chat bots (e.g. customer service, telemedicine) Mass content generation to push pre-defined narratives

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Ch 2: Habitat / *Types of Bots*

Proposed Work

- What is the habitat (social network) that different types of bots live in?**
- What are the characteristics of different types of bots?**

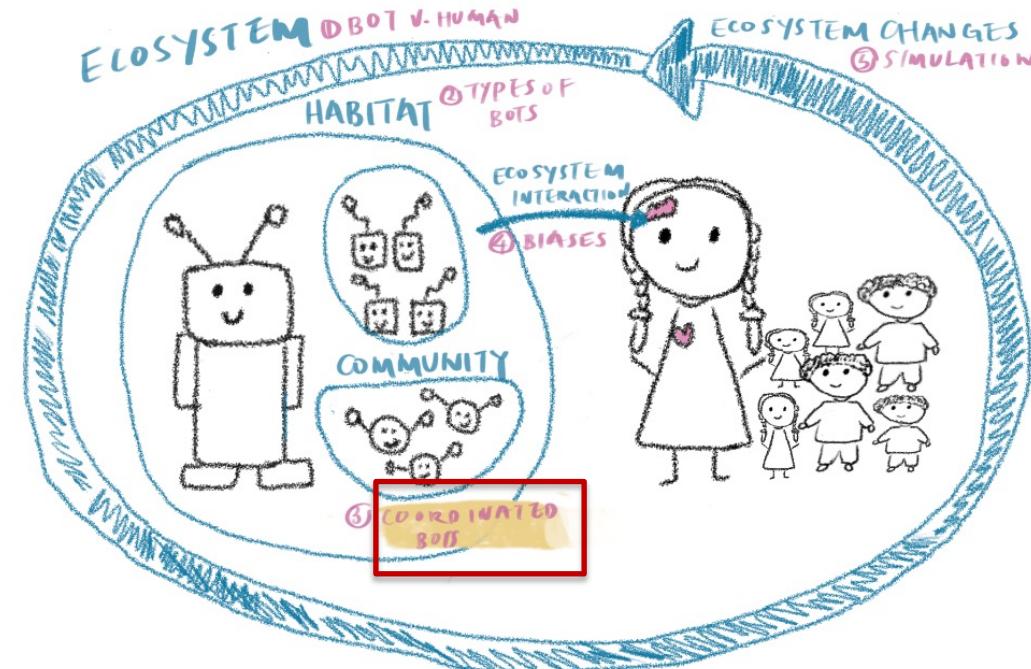
- Development of in-depth case studies to show the key properties of each bot type using our collected data
- Analyze characteristics via the comparison of linguistic cues and patterns of network interactions between bots and bots/humans
- Validates the ability of our methodology in detection of each type of bot

Ch 2: Habitat / *Types of Bots Contributions*

- Break down the generic Bot type into several commonly occurring archetypes based on their behavioral characteristics
 - Expands and harmonizes previous taxonomies that defines subtypes in terms of *what* bot users are, rather than *how* they operate
 - Behavioral characteristics ensure more timeless bot definitions
- Propose computational methods to automatically identify bots
 - Integrated-Types-Of-Bots identification tool
- Publications:
 - *Tracking China's Cross-Strait Bot Networks Against Taiwan*. SBP-Brims, 2023
- Planned Publication: The Big Book of Bots

Ch 3: Community / *Coordinated Bots* Guiding Questions

- How do bots synchronize with each other to disseminate information?
- How do bots coordinate together to increase influence?



Ch 3: Community / *Coordinated Bots* *Completed Work*

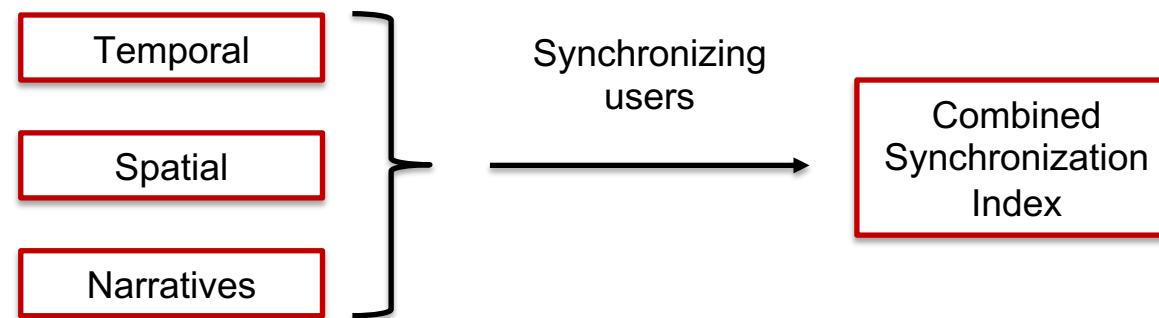
- **How do bots synchronize and coordinate with each other?**
- Synchronization: phenomenon where many users simultaneously perform the same action
- Coordination: deliberate synchronization
- Coordinated groups on social media can pose a threat to the social fabric
 - Organization of campaigns and protests
 - Analysis of 16 countries revolving around the 2011 Arab Spring protests show correlation between online synchronization and offline protests ¹
 - Analysis of similar texts in the 2021 United States Capitol Riots reveal groups of user clusters supporting disinformation narratives and themes, and we did observe an actual riot echoing some themes present on social media ²

¹ Steinert-Threlkeld, Z.C., Mocanu, D., Vespiagnani, A., Fowler, J.: Online social networks and offline protest. EPJ Data Science 4(1), 1–9 (2015)

² Ng, L. H. X., Cruickshank, I. J., & Carley, K. M. (2022). Coordinating Narratives Framework for cross-platform analysis in the 2021 US Capitol riots. Computational and Mathematical Organization Theory, 1-17.

Ch 3: Community / *Coordinated Bots* *Completed Work*

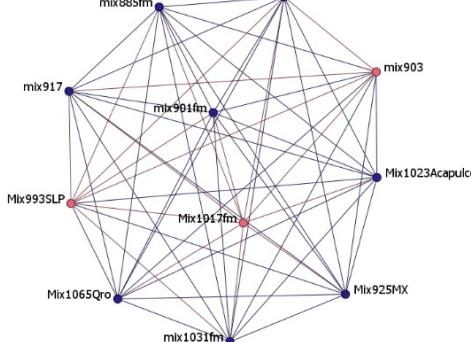
- ❑ How do bots synchronize and coordinate with each other?
- ❑ Defined Frameworks of Synchronization across three dimensions
 - ❑ Temporal, Spatial, Narratives
- ❑ Formulated a Combined Synchronization Index to rank users with different amounts of coordination across each dimension



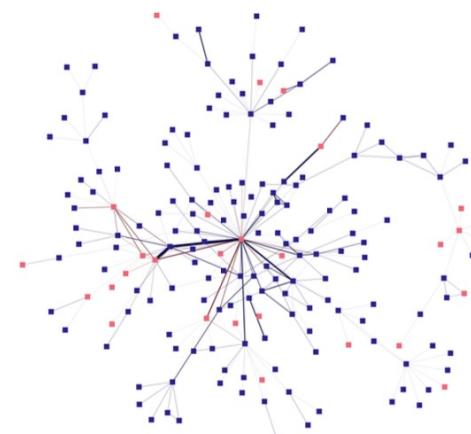
Ch 3: Community / *Coordinated Bots* *Completed Work*

Coordination across time ¹

- Identifies users that employ a defined social media mechanic (e.g. post same hashtag/ @mention) within a short time window.
- Users that employ a high frequency of a combination are termed to be synchronized



(a) Bot Network 1. All accounts were suspended a year later.

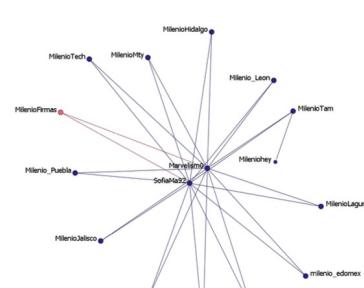


(b) Bot Network 2. 70% of the accounts were suspended a year later and some still-remaining accounts are self-declared bot accounts.

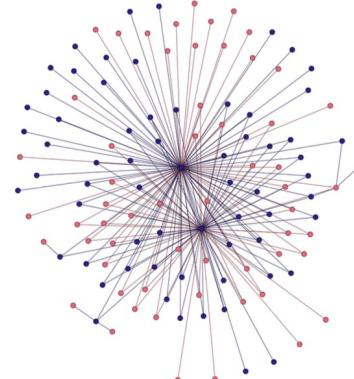
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Ch 3: Community / *Coordinated Bots* *Completed Work*

- ❑ Coordination across space ²
 - ❑ Cross-platform coordination across Twitter, Parler etc.
 - ❑ Analysis of users with similar texts and URLs across social media platforms
 - ❑ Texts are represented in a vector form (e.g. using BERT) and compared via a distance metric (e.g. Euclidean)
 - ❑ URL expansion techniques use to match URLs within posts



(a) Bot Network 1. These are announcement bots with the prefix "millenia". All accounts were suspended a year later.

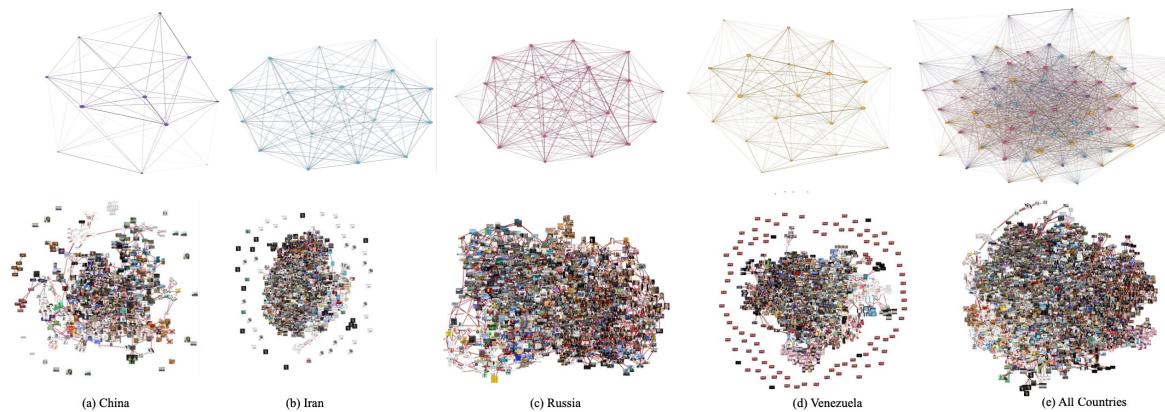


(b) Bot Network 2. 57% of the accounts were suspended a year later.

² Ng, L. H. X., Cruickshank, I. J., & Carley, K. M. (2022). Coordinating Narratives Framework for cross-platform analysis in the 2021 US Capitol riots. *Computational and Mathematical Organization Theory*, 1-17.

Ch 3: Community / *Coordinated Bots* *Completed Work*

- Coordination across narratives ³
 - Identifies users that post similar texts
 - Texts are represented in a vector form (e.g. using BERT) and compared via a distance metric (e.g. Euclidean)
 - Identifies users that post similar images
 - Images are represented in a vector form (e.g. using ResNet50) and compared a distance metric (e.g. Euclidean)



³ Ng, L., Moffit, J. D., & Carley, K. M. (2022). Coordinated through a Web of Images: Analysis of Image-based Influence Operations from China, Iran, Russia, and Venezuela. ICWSM. <https://doi.org/10.36190/2022.43>

Ch 3: Community / *Coordinated Bots* *Completed Work*

- Combined Synchronization Index ⁴
 - Measure a user coordination across the different coordination dimensions
 - Provides an overall quantification of coordination across dimensions within an event, allows for ranking of users
 - Performed study across 6 Twitter datasets, shows that the bot-bot pair exhibits most synchrony
 - Harmony and dissonance of index with network centrality values: organic/inorganic coordination
 - Formulation of this index integrated into the ORA software under “Coordination Analysis” report

⁴ Ng, L. H. X., & Carley, K. M. (2023). A combined synchronization index for evaluating collective action social media. *Applied network science*, 8(1), 1.

Ch 3: Community / *Coordinated Bots*

Proposed Work

- How do bots coordinate together to increase influence?**
- Use the Combined Synchronized Index to compare the extent of coordination of bots, and even different types of bots in different events
- Quantify the co-relation between coordination and influence

Ch 3: Community / *Coordinated Bots Contributions*

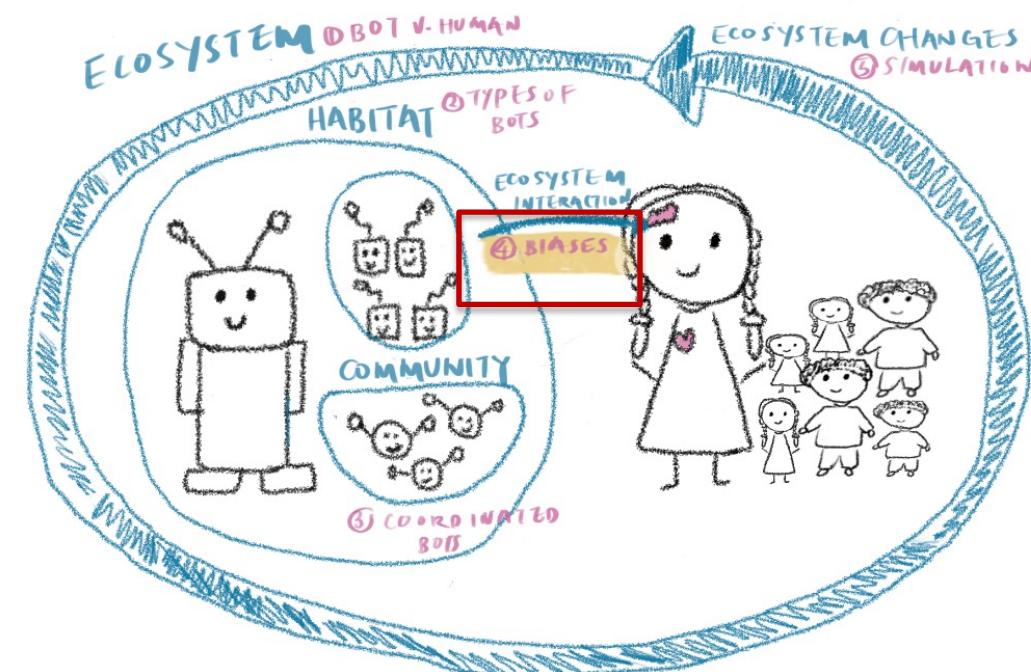
- ❑ Development of methods to identify synchronization and coordination between large groups of users
- ❑ Development of Combined Synchronization Index to rank users
- ❑ Quantify the impact of coordination with influence of users

- ❑ Publications:
 - ❑ *Coordinating Narratives Framework for cross-platform analysis in the 2021 US Capitol Riots.* CMOT, 2022
 - ❑ *A Combined Synchronization Index for Evaluating Collective Action on social media.* Applied Network Science, 2023
 - ❑ *Online Coordination: Methods and comparative case studies of coordinated groups across 4 events in the US.* Web Science, 2022.
 - ❑ *Do you hear the people sing? Comparison of synchronized url and narrative themes in 2020 and 2023 French protests.* Frontiers in Big Data, 2023

Ch 4: Ecosystem Interaction/ *Biases*

Guiding Questions

- ❑ What are the types of human biases that bots make use of?
- ❑ Do different types of bots target different biases?



Ch 4: Ecosystem Interaction/ *Biases*

Completed Work

- What are the types of human biases that bots make use of?**
- Structural biases: different demographic slices react differently
- Social-cognitive biases: different social groups interpret the same information differently
- Cognitive bias: description of human systematically flawed patterns of responses to judgment, thereby creating their own versions of social reality based on personal sensory input^{1,2}

¹ Bless, H., Fiedler, K. and Strack, F. (2004) *Social cognition: how individuals construct social reality*. Hove, UK: Psychology Press. ISBN: 9780863778292.

² Lazer, D., Baum, M., Grinberg, N., Friedland, L., Joseph, K., Hobbs, W., & Mattsson, C. (2017). Combating fake news: An agenda for research and action.

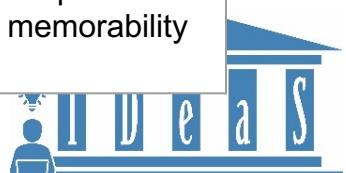
Ch 4: Ecosystem Interaction/ *Biases*

Completed Work

- Do different types of bots target different biases?**
- Profile the biases and examples of types of bots that make use of those biases
- Describe the usage in terms of the TTP framework
 - Tactic: General intent
 - Technique: Methods employed
 - Procedure: Step-by-Step implementation process

	Cognitive Bias	Definition	Type of Bot	Tactic	Technique	Procedure
Information Overload	Illusory Truth Effect	Prioritization of familiarity over fact	Repeater Bots	Create an illusion that the message spread is truth	Excessively repeating the message to flood the landing pages of human users	Excessive posting of the same message; work together as a group to post a variant of same message
	Multiple Source Effect	Presenting same content from multiple sources	Amplifier Bots	Create illusion that message is credible because many sources share the same content	Share content from multiple sources with same messaging/stance	Share the same content from established outlets
	Motivated Reasoning	Subscribing to the same view as the others around to reduce cognitive dissonance	General Bots	Create illusion that there is consensus	Identify prevailing stance that a bot is central to and change stance	Change presented stance through message posted
Societal Bias	Authority Bias	Look towards trusted sources or depend on amount of support an opinion has to determine credibility	Aggregator Bots	Establish credibility through using authority sources	Shares information from established sources and authority figures	Quoting authorities or established sources within posts
	Homophily	Associate oneself with similar others	Content Generation Bots	Present an identity that matches the group of users	Identify the dominant identity of group and create content that conforms	Generating content that matches a particular identifier of community of users
	Availability Cascade	Collective belief gains more plausibility through increased repetition	Repeater Bots	Persuade others through memorable texts	Increase ease of recollection of fake news	Using narratives and memorable quotes to increase memorability of text

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Ch 4: Ecosystem Interaction/ *Biases* *Proposed Work*

- ❑ Characterization of biases with respect to bot behavior
- ❑ Identify the presence of biases within social media platforms
 - ❑ Facebook, Instagram, Twitter
- ❑ Profile the usage of biases with Tactic, Technique, Procedure
- ❑ Development of case studies across multiple platforms to showcase the existence and generalizability of the biases

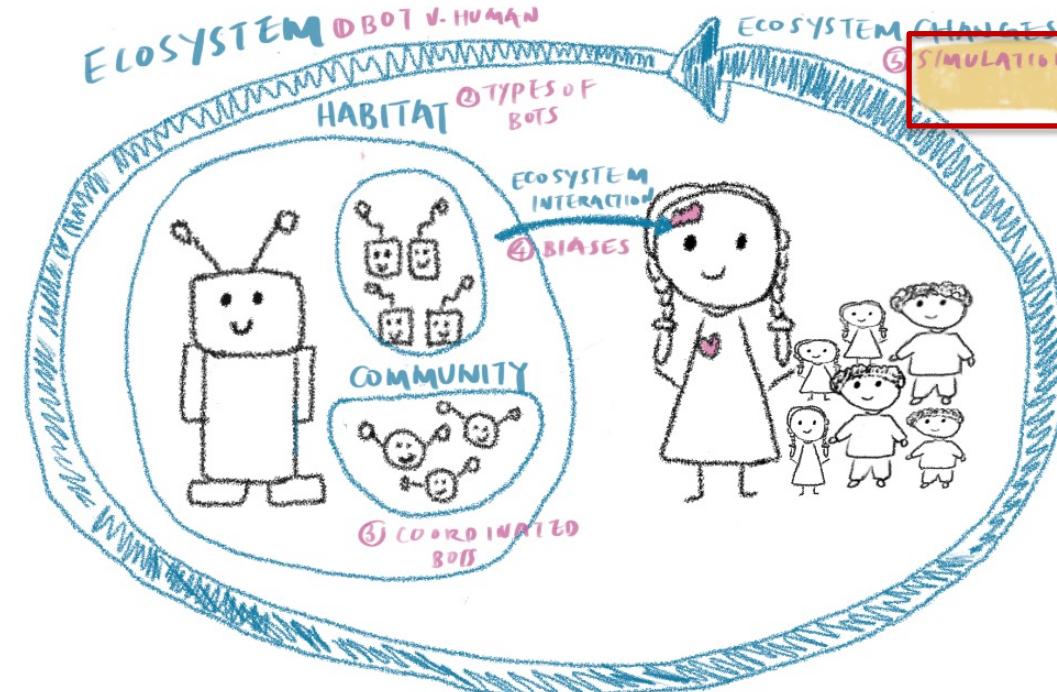
Ch 4: Ecosystem Interaction/ *Biases Contributions*

- Development of mapping of type of bots to biases deployed
- Empirical analysis of deployment of biases through case studies

- Planned Publications: 1 journal paper

Ch 5: Ecosystem Changes / *Simulation as a Test Bed Guiding Questions*

- ❑ How much pressure from bots is required to change the ecosystem?
- ❑ Will the ecosystem ever reach a steady state?



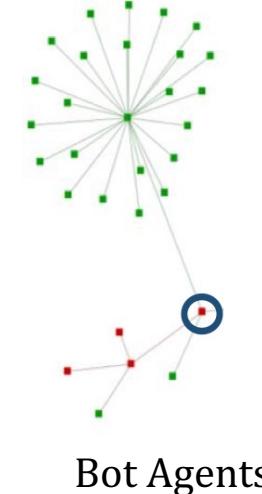
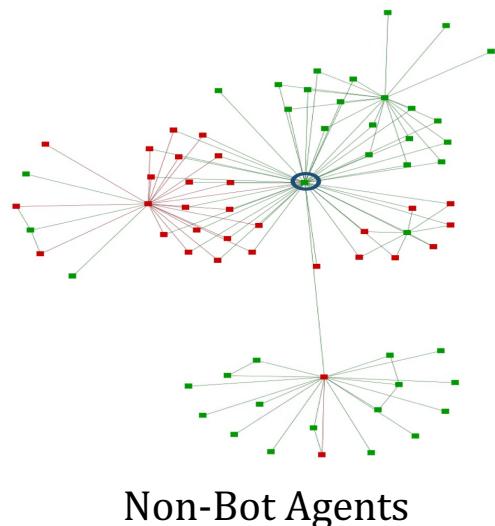
Ch 5: Ecosystem Changes / *Simulation as a Test Bed Completed Work*

- How much pressure is required from bots to change the ecosystem?**
- Simulation is a technique to model the complex and interconnected relationships and interactions between social media users and project the dynamics into the future
- Construct interactions and opinions based on collected and annotated real data
 - Form base
- Construct interactions and opinions based on collected and annotated real data
 - Form base network structures
 - Provide parameters to model change in opinions over time
- Social Influence Model¹
 - Intrinsic properties (linguistic properties of texts in previous posts)
 - Extrinsic environment (network connections with other users)

¹ Friedkin, N. E., & Johnsen, E. C. (1990). Social influence and opinions. *Journal of mathematical sociology*, 15(3-4), 193-206.

Ch 5: Ecosystem Changes / *Simulation as a Test Bed Completed Work*

- Social network structure can affect the expression of online stances¹
 - Changes to online stances towards the coronavirus vaccine has been observed
 - Changes (or not) dependent on neighboring agents
 - Bots require less pressure to change stances



¹ Ng, L. H. X., & Carley, K. M. (2022). Pro or Anti? a social influence model of online stance flipping. *IEEE Transactions on Network Science and Engineering*, 10(1), 3-19.

Ch 5: Ecosystem Changes / *Simulation as a Test Bed* *Proposed Work*

- Will the ecosystem ever reach steady state?**
- Develop Agent-Based Model to model the changes in stances/ emotions
Assuming no external influence except peer pressure,
 - Will the overall opinions within this network converge? Or will they polarize into multiple opinion groups?
 - Will the users ever stop changing their stances?
- Agents are developed based on the bot/human characteristics observed from previous chapters
- Determination of parameters for steady state bot-human interaction, if any

Ch 5: Ecosystem Changes / *Simulation as a Test Bed Contributions*

- ❑ Combining study outputs from previous chapters in terms of Bot-Human interaction to create realistic simulated scenarios
 - ❑ Aids in scenario projection and evaluation without altering the actual social network
- ❑ Provide a way to extensively examine social network changes across time
 - ❑ Bot-Human interactions
 - ❑ Bot-Human discourse
- ❑ Publications
 - ❑ The Big Book of Bots
 - ❑ *Pro or anti? A social influence model of online stance flipping.* IEEE Transactions on Network Science & Engineering, 2022
 - ❑ *Simulation of Stance Perturbations.* SBP-Brims, 2023.
- ❑ Planned: 1 journal paper submission

Limitations

- Largely Twitter-based due to availability of annotated data and ease of collection
 - Have also evaluated other platforms: Reddit, Instagram
 - Mainly study bots within and across common social media platforms (Twitter, Reddit, Instagram)
 - New forms of platforms and new medium are discussed but their study of bots is beyond the scope of this thesis
- Largely English based studies
 - Complementary studies of bots in other languages are suggested by literature but are beyond the scope of this thesis
 - Developed tools may be adapted to address these
- Changing bot behavior leads to evasion of bot detection techniques
 - Fundamental behavioral characterizations should remain unchanged
 - Detection and characterization methodologies will evolve with new social media platforms and mediums

Summary of Contributions

- ❑ Theoretical
 - ❑ Definitions and fundamentals of social media ecosystems
 - ❑ Discussion of social aspect of social media bots
 - ❑ Large scale study of bot activity and behavior across global and regional events
 - ❑ Bot typology to characterize bots by online behavior and actions
- ❑ Methodological
 - ❑ Development of bot detection classification algorithms
 - ❑ Development of type-of-bots clustering algorithms
 - ❑ Development of bot simulation methods
- ❑ Academic
 - ❑ The Big Book of Bots
 - ❑ Publications: ICWSM, Online Social Networks and Media, IEEE Network Science and Engineering, SBP-BRIMS
 - ❑ Planned Publications: Big Data & Society, ACM journal, Simulation journal

Summary of Completed/Planned Work

Chapter	Completed Work	Planned Work
Ch 1: Bots vs Humans	<ul style="list-style-type: none">Development of bot detection by classification modelEmpirical analysis over large corpus of dataset	<ul style="list-style-type: none">Refinement and write up of empirical analysis
Ch 2: Types of Bots	<ul style="list-style-type: none">Baseline typology establishedDevelopment of types-of-bot identification technologies across large corpus	<ul style="list-style-type: none">Development of integrated Types-Of-Bots detection modelDevelopment of case studies for each type of bot
Ch 3: Coordinated Bots	<ul style="list-style-type: none">Development of Framework for identification and analysis of synchronizationEmpirical analysis of temporal and narrative synchronization	<ul style="list-style-type: none">Development of framework of synchronization and coordination types
Ch 4: Biases	<ul style="list-style-type: none">Literature review	<ul style="list-style-type: none">Development of framework that harmonizes Type of Bots with Biases
Ch 5: Simulation as a Test Bed	<ul style="list-style-type: none">Initial empirical analysis of opinion change patterns of bots and humans	<ul style="list-style-type: none">Development of bot simulation modelExecution and analysis of model

Summary of Publications

Chapter	Completed Publications	In-Progress Publications
Ch 1: Bots vs Humans	<ul style="list-style-type: none">• The Big Book of Bots• Online Social Networks and Media• International AAAI Conference for Web and Social Media• SBP-Brim• First Monday	<ul style="list-style-type: none">• The Big Book of Bots
Ch 2: Types of Bots	<ul style="list-style-type: none">• The Big Book of Bots• SBP-Brim	<ul style="list-style-type: none">• The Big Book of Bots• Big Data & Society (under review)• EPJ Data Science (under review)
Ch 3: Coordinated Bots	<ul style="list-style-type: none">• The Big Book of Bots• Journal of Online Trust & Safety• Social Network Analysis & Mining• Computational & Mathematical Organizational Theory• Applied Network Science• ACM Web Science Conference• Social Media + Society	<ul style="list-style-type: none">• Frontiers in Big Data, Misinformation and Misbehavior Mining on the Web (under review)
Ch 4: Biases		<ul style="list-style-type: none">• 1 journal paper
Ch 5: Simulation as a Test Bed	<ul style="list-style-type: none">• The Big Book of Bots• IEEE Transactions on Network Science and Engineering• SBP-Brim	<ul style="list-style-type: none">• 1 journal paper

Timeline of Completed Work

	Spring 2021	Fall 2021	Spring 2022	Fall 2022	Spring 2023	Fall 2023
Ch 1: Bots vs Humans						
Development of bot classification model		✓				
Establishment of bot vs human analysis methodology		✓	✓			
Empirical analysis over large dataset	✓	✓	✓			
Ch 2: Types of Bots						
Development of baseline typology through literature synthesis			✓	✓		
Development of types-of-bots identification technologies and applications to large dataset			✓	✓	✓	
Ch 3: Coordinated Bots						
Development of frameworks for identification and analysis of synchronization		✓	✓	✓	✓	
Empirical analysis of temporal and narrative synchronization	✓	✓	✓		✓	
Ch 5: Simulation as a Test Bed						
Development of social influence model of opinion change	✓	✓	✓			

Timeline of Planned Work

	Fall 2023	Spring 2024	Fall 2024	Spring 2025	Fall 2025	2026
Ch 1: Bots vs Humans						
Refinement and write up of empirical analysis	√					
Ch 2: Types of Bots						
Development of integrated Types-Of-Bots detection model	√	√	√	√		
Development of case studies of Types of Bots	√	√	√	√		
Ch 3: Coordinated Bots						
Development of framework of coordination types		√	√			
Ch 4: Biases						
Harmonization of types of bots with biases		√	√	√		
Ch 5: Simulation as a Test Bed						
Development of bot simulation model				√	√	
Execution and analysis of model				√	√	
Finalize Thesis Document						√
Thesis Defense						√

END

Lynnette Ng

Thesis Proposal

Advised by Professor Kathleen M. Carley

The CMU center for Informed DEMocracy And Social cyber-security



Carnegie Mellon University

