Research Statement

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1 Introduction

In an era where technology has amplified the amount of publicly available information, inadvertently opening the door for dissemination of data from misleading sources, the emergence of community science, where laypeople collectively contribute to real-world problems, has been viewed as a powerful facilitator for bringing people together, motivating public engagement, challenging official accounts and driving policy change (13; 16). From disaster response (2; 17; 18) to biodiversity (11; 20) and environmental justice (8; 32), community science focused crowdsourcing systems showcase great promise towards encouraging people to collaborate for social change. My work contributes towards this direction by building systems that can enable collaborative, distributed work on shared social problems. As a result, my main research interests lie at the intersection of Human Computer Interaction, crowdsourcing and games, with an emphasis on *"HCI for Good"*. Through the years, my research has evolved around building crowdsourcing platforms that can empower the general public to not only contribute to, but also gain a better understanding on challenging issues that may lead to big social impacts. Specifically, I seek to uncover intrinsic motivation factors that can have a positive effect on crowd participation and output quality. These factors can be instrumental in designing processes with an aim in transforming community work into actionable items for impacting decision making, policy change and advocacy efforts.

The two core research strands that encompass my work are:

■ *How can we design effective interfaces for motivating engagement in community science?* External motivation factors such as monetary rewards may not be viable options in community science efforts, that mainly rely on volunteer work. Work in the crowdsourcing domain has linked monotony to negative impact on performance (14), and shown that ordering and continuity of tasks can boost participant engagement (5; 7; 15), while collaboration and competition feature heavily in the domain of games and are highly suited for adaptation in crowdsourcing(31). To this end, I have focused on exploring intrinsic motivation, such as task variety mechanisms, as well as the interplay between collaboration and competition, in crowdsourcing systems (24; 25; 26; 27; 28). My work on this research strand so far has examined image labeling as one type of task, and has also resulted in the creation of three interconnected systems within this context: Cartoscope, an open-sourced crowdsourcing platform that aims to connect organizations with volunteers (6), Tile-o-Scope Grid, an image matching web game, where players are tasked with sorting images into categories by drawing lines to connect them (30), and Tile-o-Scope AR, an Augmented Reality tabletop toolkit for image labeling (29).

■ *How can we improve readers' comprehension by eliciting helpful analogies for unfamiliar measurements?* Decision making across multiple domains is increasingly relying on data-driven solutions. This results in the public becoming exposed to an unprecedented volume of unfamiliar measurements that are difficult to comprehend. Therefore, designing effective frameworks for helping the crowd better understand these measurements can be crucial in mitigating decision errors that stem from their incorrect interpretation (22). To this end, I have been involved in the development of the Perspectives Engine, an AI tool for automatically generating helpful analogies for unfamiliar measurements. My work so on this research strand so far has focused on designing interfaces for eliciting high quality reference objects from the crowd, as well as developing inclusive models for automatically surfacing helpful reference objects depending on given contexts.

The remainder of this statement is organized as follows: Section 2 provides more information on my research findings and developed systems regarding the first strand, on designing effective interfaces for motivating engagement in community science. Section 3 covers ongoing work on the second strand, which deals with improving readers' comprehension by eliciting helpful analogies for unfamiliar measurements. Finally, Section 4 provides an overview of research directions I am excited about exploring in the future. Section 5 offers a summary of my service and outreach efforts.

2 Designing Effective Interfaces for Motivating Engagement in Community Science

Within the first core strand of my research, I have focused on designing open-sourced interfaces for community science, that may be rapidly deployed by smaller organizations in community engagement and advocacy efforts. Identifying and utilizing intrinsic motivating factors is essential in such settings, which rely on voluntary contributions, rather than

monetary incentives. I've primarily explored *image labeling* oriented tasks, which are extremely popular across multiple community science applications. Within this setting, I have explored three directions; *traditional*, *gamified*, and *co-located* interfaces. The following subsections cover my research work within each direction, as well as tools that I have developed as part of my research.

2.1 Traditional Online Interfaces

An interface is considered *traditional* when it is set up to include the bare essentials for the task to be completed. Traditional interfaces can be an appealing option due to their simplicity, that is perfectly suited for rapidly deploying community science projects in critical situations. In this context, I have examined volunteer motivations that participants bring when contributing to projects, and have explored fixed scheduling variety mechanisms for motivating engagement. My research findings have been the basis of the design and development of Cartoscope, an open-sourced crowdsourcing platform for image labeling.

Volunteer Motivations in Crowdsourced Image Labeling Tasks (9; 26). In order to gain insight into participant motivations in community science projects, and the interplay of paid versus volunteer work, we conducted a study, in which we recruited participants to label aerial imagery from the Colorado Floods in 2013 (26). We deployed a *required work payment scheme*, where participants recruited from Amazon Mechanical Turk were paid a fixed amount to provide *at least* some minimum number of labels, after which point they could voluntarily continue labeling more images. We found that participants generally contributed more on the project due to their own interest when no minimum work requirement was asked of them. Responses from participants also revealed motivations other than payment, such as personality, abilities, and motivation due to the nature of the task (analyzing disasters), when contributing beyond the required amounts. We further explored volunteer performance, compared to paid contributors, in a retrospective analysis of an environmental justice project (9). We found that despite the potential recruitment challenges, volunteers can achieve high accuracy with fewer votes.

Fixed Scheduling Variety Mechanisms (24). In this work (best paper award nomination), we explored the use of *variety* towards improving behavioral engagement on crowdsourcing tasks(21). We designed an experiment where participants were asked to complete sequences of *image labeling* and *image mapping* subtasks. To examine the effects of variety—in terms of subtasks with different complexity—on performance, we varied how often the more complex types (maps) would appear in between simpler ones (labels). We observed no negative impacts in the quality of contributions when introducing subtask type switches. In addition, we found that interleaving a more complex subtask (maps) at a small interval (every 10 label subtasks) increased the total time *voluntarily* spent on the task without observably negatively impacting other performance metrics. Our findings offer initial support for designing task variety mechanisms to promote engagement in volunteer based settings.

Cartoscope: My research in volunteer motivations and task variety was the basis for developing Cartoscope, an open-sourced crowdsourcing platform that aims to connect organizations with volunteers (6). I have been the Lead P.h.D Researcher and Lead Developer throughout my P.h.D. studies, and continue to be actively involved in research collaborations. So far, I have collaborated with non-profit organizations such as Healthy Gulf, that have used Cartoscope for monitoring land loss in Louisiana and damage assessment after events such as Hurricane Ida, and the UniqueMappers Network in Nigeria, for raising awareness about the serious impacts of oil spills in the Niger Delta region. Cartoscope has also been featured in a museum exhibition on community science at the Cleveland Museum of Natural History in 2017, in collaboration with a research team at NASA towards identifying algal blooms in Lake Erie, OH. More recently, we partnered with Healthy Gulf to utilize Cartoscope to to conduct a crowdsourced mapping of wetland morphology associated with wetland loss and restoration in coastal Louisiana (23). This work provides a foundation for increasing public awareness for wetland loss via crowdsourced engagement, contributing to land surveys and potentially training machine learning algorithms.

2.2 Gamified Online Interfaces

One downside to traditional interfaces, which were the topic of the previous subsection,is that they may often be perceived as monotonous due to their simple, no-frills nature. One popular approach towards mitigating negative impacts induced by this monotonicity revolves around introducing various gamification elements. Within this direction, I have expanded my previous work on scheduling variety mechanisms, by examining both variable, and adaptive algorithms. I have also utilized my research findings in this direction to develop an online crowdsourcing web game, which has been used for image labeling.

Variable & Adaptive Scheduling Variety Mechanisms (27; 28). In continuation of my previous work on task variety in traditional interfaces, we proceeded to explore Reinforcement Learning (RL) for leveraging task variety in motivating engagement in community science oriented tasks. We first designed a non-adaptive difficulty sequencing approach based on the Q-learning algorithm, to generate sequences of level difficulties for players in an online image matching game(27). Our Q-learning approach outperformed a uniform random approach for task variety, in metrics like tile collections and time spent, and a greedy approach,in level completion, time per level, and move length. We then designed an adaptive extension, that incorporates participant performance in sequencing the difficulty of levels (28), which we found outperformed both the previous non-adaptive version, as well as a greedy approach, in terms of total reward collected. Introducing a messaging system based on Cairns (human-made piles of rocks which are often encountered in long-distance hiking trails) revealed promising future research directions in building community in community science projects.

Tile-o-Scope Grid. In support of my research on gamified online interfaces, I have also developed Tile-o-Scope Grid (TG), an image matching web game, where players are tasked with sorting images into categories by drawing lines to connect them (30). TG uses Reinforcement Learning based algorithms for serving levels of varying difficulty to players. Contrary to Cartoscope, this tool allows for batch labeling, which can be better suited for bigger datasets. Our tool has been featured in the Citizen Science Association Festival that took place at the North Carolina Museum of Natural Sciences in 2019.

2.3 Co-Located Image Labeling

One common factor across the two previous approaches is their inherent individuality, as participants tend to contribute in an online, single-player fashion. In this segment, I explored approaches that can promote in-depth discussions between participants, which can be a powerful facilitator for building shared awareness and a sense of community (1; 3; 4; 33). Work on this direction has also led to the development of an Augmented Reality image labeling toolkit.

Exploring Co-Located Image Labeling via an Augmented Reality Tabletop Image Labeling Game Toolkit (27; 28). In this body of work, we explore incorporating physical elements and in-person community-based gameplay for crowdsourced image labeling, by developing an augmented reality game toolkit called Tile-o-Scope AR. We first conducted an exploratory user study on our design where we found that, even when starting from a competitive setting, all participant groups started collaborating immediately, exchanging ideas and sharing observations, even if this action would effectively help their opponents . Through brainstorming, participants came up with a variety of games, ranging from adapting existing games for the toolkit to novel ideas, with a wide range of applications. Thematic analysis on a subsequent study we conducted comparing the AR version to a browser based interface revealed that while a browser interface may be better suited to rapid, accessible, productive play, TOSAR is better suited to reflective, one-time, unstructured experiences. Our findings reveal potential for exploring TOSAR in contexts such as classrooms and museums.

Tile-o-Scope AR. As part of my research work in facilitating deeper connections among participants and exploring how collaboration and competition affects engagement in co-located settings, I worked on developing **Tile-o-Scope AR**, a multi-person, co-located image labeling toolkit that can be played using physical tags and a mobile device such as a phone or tablet. The game utilizes Augmented Reality (AR) to read physical tags and translate them into images on the device, which can then be sorted into categories. TOSAR is designed in a customizable manner, which allows players to come up with their own games to achieve image labeling while playing. Our tool has been featured in a museum exhibit for Citizen Science Festival 2019, at the North Carolina Museum of Natural Sciences, as well as in Healthy Gulf's community outreach events.

3 Improving Readers' Comprehension

Beyond my research on crowdsourced image labeling, I have also been involved in projects aimed at improving reader comprehension by generating helpful analogies for unfamiliar numbers. Re-expressing unfamiliar numbers can greatly promote comprehension of scientific data currently used to drive significant change in domains such as environmental justice, public health and more. In particular, I have worked on the **Perspectives Engine**, that aims to generate helpful analogies for unfamiliar numbers encountered in the news and other sources (19). My work in this direction combines crowdsourcing, interface design and machine learning to tackle the challenge of generating and ranking meaningful analogies, for a variety of measurements.

Comparing scalable strategies for generating perspectives *(under review).* In this work, we develop and compare three policies of varying complexity for generating perspectives for monetary amounts: a) a simple rule-based approach of re-expression, b) a crowdsourced system for generating, ranking and verifying perspectives and c) a BERT embeddings based model for generating contextual perspectives. Findings from our evaluation study reveal heterogeneity both in terms of user preferences, and in terms of preferences across different settings, highlighting that a combination of the three policies via an additional layer of intelligence is optimal.

A computational model for surfacing helpful perspectives *(working paper).* Prior work has shown that crowdsourcing can be powerful for generating perspectives, however, it may often times be non-inclusive, as what is considered helpful to one region may not be relevant to other regions. In this work, we develop generalized computational models for ranking large volumes of perspectives for multiple types of measurements. We identify and evaluate different proxies for helpfulness and familiarity and study our models' adaptability towards generating suggestions to different language contexts, leading to more inclusive perspectives.

Crowdsourcing Perspectives. In support of my research work in improving reader comprehension, I have developed a crowdsourcing platform for eliciting reference objects from the crowd. These objects can then be used to re-express numbers and quantities which are hard to comprehend, into familiar and easy to visualize analogies. Reference objects that I have collected using this tool are currently deployed in Microsoft's PowerPoint for suggesting useful analogies as part of the Design Ideas feature.

4 Future Research Agenda

My research work thus far, combining Human Computer Interaction with crowdsourcing, gaming and machine learning elements, has revealed promising future directions in empowering community participation towards decision making and advocacy efforts. I wish to continue developing tools and models along the two core research strands of my research:

Enhancing large scale community science efforts for climate change and environmental justice: Mitigating climate change is considered the most pressing issue of our times and community science can play a key role. However, disengagement has been shown to be a major hindrance towards successful operations. By designing algorithms that can improve participant retention, leading to more contributions, we can bootstrap more substantial efforts in advocacy, monitoring and accountability initiatives. In the long term, platforms such as Cartoscope could be useful to federal agencies as well (e.g. EPA) in assisting in public agenda setting for scientific and environmental health research.

I aim to develop more adaptive mechanisms for leveraging task variety in crowdsourced tasks. Although my current work on dynamic scheduling of subtasks has focused on Q-learning based algorithms, I wish to explore other Reinforcement Learning algorithms and their effectiveness towards participant retention and improved crowd performance. I am also particularly interested in building inter-community connectedness through collaborative systems geared towards facilitating collective advocacy. My research on using elements such as Augmented Reality(AR) for collaboration has revealed promising future directions to that end, raising the challenge to not only further explore AR within image labeling, but also in other domains.

Improving comprehension of complex information: The general public gets increasingly bombarded with multiples of conflicting information from differing sources. It therefore becomes imperative to have systems in place for assisting audiences in parsing and reasoning with this information, so as to facilitate better decision making and combat the dangers of misinformation. I wish to continue contributing towards this area through actively building tools for enhancing and summarizing difficult to understand pieces of information.

Working on the Perspectives Engine has offered me valuable insights for further work in this area. More specifically, I wish to further explore mechanisms for combining crowd knowledge and expertise with Machine Learning for generating valuable context for different types of content. Human assessments can be crucial in such settings, yet they pose significant challenges in terms of scalability. I view my ongoing work on computational models for generating helpful analogies as a great starting point towards this direction. I hope to continue studying factors that greatly contribute in facilitating information digest and interpretability, and develop automated systems for critical domains beyond news, such as healthcare and legislation. I consider designing inclusive solutions a core priority for my future work.

Finally, I aim to continue exploring gamification applications for both core research strands, motivated by my research findings thus far. I am particularly interested in the interplay between collaboration and competition and its impact on crowdsourced settings. One promising future direction is towards building on my current work on co-located tabletop Augmented Reality games to further utilize a combination of collaborative and competitive mechanics to foster deeper engagement with tasks and increase crowd performance. Given the great potential that these techniques hold towards broader applicability, I see great value in further exploring such solutions on other domains. To illustrate how collaborative work on image labeling can be applied to different contexts, we can consider introducing similar mechanisms to a tool such

as the Perspectives Engine as one example. In particular, we can extend the current system to encourage participants to collaborate in order to suggest better analogies than the current best, and observe how this collaboration impacts their performance and retention levels. Gamification can also be used in improving comprehension of complex information. We can develop engaging and playful interactions to benefit long term knowledge and reasoning with unfamiliar quantities.

5 Service and Outreach Activities

During my PhD and postdoctoral studies, I have served as a reviewer for CHI (2022), Citizen Science: Theory and Practice (2021), IEEE Transactions on Games (2020) , CHI PLAY (2019), ISCRAM (2018), and CitSci (2017), and served as PC member for FDF (2017,2021). I have also had the opportunity to develop my mentoring skills, as a Teaching Assistant for the PhD level core course CS7340 (Theory and Methods in HCI). My responsibilities included giving lectures and leading in-class activities, as well as mentoring students towards reading scientific papers, giving presentations, and preparing HCI reports on their final projects. Aiming to hone my critical thinking skills on research outside my field, I have also served as a reviewer for Origin, a student-led Tech Hub for entrepreneurship, from Fall 2017 to Spring 2019. In this role, I was in charge of evaluating ventures that enter into the program and assessing their commercial viability for awarding funding to build prototypes.

I've strongly believed in creating opportunities for socialization outside of specific research groups. While at Northeastern University, I was the main organizer of the PhD Women Group, a group for female-identifying PhD students. The group is meant to serve as a platform for networking, discussion of special interest topics, and as a neutral and safe social space for its members. As an organizer, I have been responsible for coordinating meet-ups, guest talks with invited speakers, as well as off-campus activities. I was also the creator of the group's website (12). Additionally, I have been the lead organizer of the PhD Social Hour, a weekly networking event for students. In 2019, I was elected by my peers as the student representative in the PhD Admissions Committee. My role included serving as a reviewer for PhD applications, as well as co-organizing the upcoming PhD Open House. In 2021, I received the KCCS PhD Community Service Award, as a recognition of my efforts in organizing and advocating for PhD students. This award is reserved for exceptional cases and not awarded annually.

During my time as a post-doctoral researcher at Microsoft Research NYC, I served in the organization committee for the annual Giving campaign twice, where I helped organize events towards raising awareness and encouraging contributions to charitable organizations. Part of my duties as organizer included inviting speakers from various organizations, and organizing events where lab members collectively contributed to causes. I also co-lead an initiative where lab members can share about causes they contribute to and feel passionate about.

I have been fortunate to be involved in research that encourages getting in contact with local communities and collaborating towards assisting their respective projects and agenda. One such collaboration resulting from my research work on the Cartoscope platform has been with Healthy Gulf, a non-profit organization based in Louisiana (10). Healthy Gulf is committed to advocating for protection and restoration of the natural resources in the Gulf Region. Part of my involvement has included aiding the organization of public events in New Orleans, as well as having discussions with local community members about their experiences.

My experience so far has shown that research can only thrive when being conducted in diverse and inclusive environments, where different voices and perspectives can be heard. I am committed to continuing my involvement in similar initiatives towards fostering such environments in my post PhD academic career, building on the organizational knowledge I acquired at Northeastern University and Microsoft Research.

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