Gaming for (Citizen) Science

Exploring Motivation and Data Quality in the Context of Crowdsourced Science Through the Design and Evaluation of a Social-Computational System

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***Abstract*—*Citizen Sort*, currently under development, is a web-based social-computational system designed to support a citizen science task, the taxonomic classification of various insect, animal, and plant species. In addition to supporting this natural science objective, the *Citizen Sort* platform will also support information science research goals on motivation for participation in social-computation and citizen science. In particular, this research program addresses the use of games to motivate participation in social-computational citizen science, and explores the effects of system design on motivation and data quality. A design science approach, where IT artifacts are developed to solve problems and answer research questions is described. Research questions, progress on *Citizen Sort* planning and implementation, and key challenges are discussed.**

Citizen Science; Social Computational Systems; Games; Gaming; Motivation; Participation; Data Quality; Design; Design Science

I. Introduction

Citizen Science is a term used to describe research collaborations where members of the public are recruited to assist with scientific investigations [1, 2]. Citizen science projects include (for example) those that ask participants to classify photographs of galaxies taken by space telescopes, report bird sighting data for ornithological research, or plant sunflowers and observe bee pollination at various times during the day. Additional examples abound. Citizen science projects bring together large numbers of individuals, each of whom contribute a relatively small portion of the overall effort.

The ongoing design research project described in this paper frames citizen science projects as a form of social-computational system. Social-computational systems are those where human participants and computer technologies work in coordination to produce results that neither could alone. Similarly, in many citizen science projects human beings and computer technologies each have a role to play in generating usable scientific data. Human participants contribute perceptual and cognitive abilities, as well as expert knowledge, far outside the realm of practicality for the current state of the art in computation. Computer technologies are used to support and augment these human abilities, making them more efficient, accurate, and reliable.

Social-computational systems involve large numbers of individual human beings who are asked to perform some sort of work as part of a larger and more complex pursuit. The kinds of tasks that humans undertake are sometimes mundane or repetitive, but may also be complex, requiring specialized training or knowledge. This raises significant questions about participant motivation in social-computational systems. Project participants are human beings, and not simply organic CPUs, so making tasks enjoyable and motivating is important. The successful social-computational system for citizen science will find ways to persuade participants to become involved and then stay involved. It will look for ways to reduce human disinterest and error by drawing upon the best of both the human and computational worlds.

Data quality is a second factor of interest in this research. Human beings are imperfect and error-prone. Scientific endeavors require data of very high quality, but most citizen science projects intentionally place responsibility for data tasks into the hands of non-experts. It has been demonstrated that citizen science efforts often produce high quality data, but open questions remain: how do the motivational techniques employed by citizen science projects affect data quality? How do expert and non-expert users differ in their approaches to data collection, and what are the repercussions for data reliability or accuracy? Does an emphasis on "fun" negatively affect data quality? Does an emphasis on quality negatively affect motivation?

We explore these issues through a *design science* approach to inquiry, a research technique that relies upon the development of IT artifacts to solve challenging problems and address research questions. In this paper, we present our plans to develop a social-computational system for citizen science called *Citizen Sort*, which will enable citizens to classify plants, animals, and insects using web-based tools and games. We include a brief literature review on design science as a method of inquiry, as well as discussions of motivation and data quality, and we present a series of research questions throughout; we intend to address these questions by evaluating the finished *Citizen Sort* system. Our concluding discussion addresses several difficult, upcoming challenges as our design research program progresses.

II. Literature Review

A. Design Science as a Method of Inquiry

We adopt the information systems definition of design science [3, 4], an approach to scholarly study that merges traditional research methodologies with an important added element: the development of an IT artifact. This artifact must satisfy three important requirements: 1) solve specific, challenging, and practical problems within a given context, 2) address significant research questions, and 3) be feasible to design and build.

Similarly, design science research contains three interrelated stages, typically addressed in an iterative, rather than linear fashion. These stages may be described as "theory," "design," and "evaluation" [5].

Theory: Design science research should include background conceptual development that may be theory- or model-based, but may also include consultation with experts or review of project-specific design literature. The word "theory" is used broadly here, as this stage also encompasses practical discovery and thorough understanding of the problem that the designed artifact will attempt to resolve.

Design: Design science research revolves around the design and implementation of a technological artifact, where the theoretical and practical underpinnings developed in the theory stage are formed into a functional system. The design stage must take future evaluation into account. During design, researchers must bear in mind the research questions that will be addressed through evaluation of the artifact. In some cases, evaluative components must be incorporated into the design of the system itself.

Evaluation: The artifact is evaluated with respect to the research questions, the problem to be solved, and its use and users. Evaluation should say more than simply whether the system worked or not; it should also provide evidence to support or reject the theories and assumptions around which the system was designed, reveal new avenues for research, and clarify the phenomenon under examination.

In design science research, the theory, design, and evaluation stages are intertwined and conducted iteratively [3-5]. While underlying theories are often adopted early in a project timeline, they may be augmented, modified, or rejected based upon the outcomes of expert interviews or other data collection efforts. The design process itself may require that researchers reflect upon the practicality or utility of certain assumptions. The evaluation process is not necessarily an end point for research. Rather, evaluation may suggest ways to modify an artifact that will either improve its utility as a problem-solving system or as an avenue to answering established research questions.

B. Motivation

Motivation has been identified by scholars and practitioners as an important aspect of crowdsourced science [6]. However, in the citizen science domain, motivation is still an emerging topic for research [7].

There has been some exploration of motivation in the context of nature conservation (for example, protecting Florida's sea turtles or studying nesting birds). These studies find that altruism, for example, "helping and protecting sea turtles," or "doing something for nature," was the primary motivations for their participants [8, 9]. However, motivating factors for projects without advocacy goals are less clear. Studies which ask participants to classify photos online or perform abstract analysis tasks may not be as motivating (in terms of altruism) as those which ask participants to go out into the world and actively help an endangered species.

One recent study of motivation in citizen science [10] uses the *Galaxy Zoo* (http://www.galaxyzoo.org) project as a case study. *Galaxy Zoo* is a citizen science initiative whereby participants are asked to view space telescope photographs of galaxies (from the Hubble, Sloan, and other telescopes) and provide classification data about them. For example, participants are asked to identify how rounded or elliptical a galaxy is, how many spiral arms it has, etc.

In study [10], *Galaxy Zoo* participants were directly asked about their motivations for participation. Twelve principal reasons were identified through a content analysis approach: Contribute, Learning, Discovery, Community, Teaching, Beauty, Fun, Helping, Zoo (interest in the *Galaxy Zoo* project specifically), Vastness (awe about the vastness of space), Astronomy, and Science. Participants were typically motivated by several of these at once. Making contributions and helping, identical to altruistic motivations identified in studies [8, 9], were just two of the possible motivators for *Galaxy Zoo* participants. Interest in the specific subject (astronomy) and related topics (vastness, science) were also important, though these similarly did not account for the entire range of participant motivations. The desire to be entertained (fun), participate in a community, learn something, and discover something unique was also important motivators for *Galaxy Zoo* participants.

For projects with inherently interesting scientific domains or clearly defined positive impacts, it may be enough to entice participation through interest in the topic or through altruism. Citizen science projects such as *eBird* [11] have successfully engaged the birding community to collect ornithological data; similarly, *Galaxy Zoo* capitalizes on popular interest in astronomy. However, the notion of fun was very prominent in the data from study [10], suggesting that projects with less established communities of interest may still benefit from citizen science approaches if they are designed to motivate and engage participants. Indeed, "fun" was the most frequently mentioned motivator for *Galaxy Zoo* participants after altruistic or intrinsic motivations such as helping out or interest in astronomy and science. Fun experiences can be created in a variety of ways; community, learning, and discovery can all be fun. The current literature on motivation in citizen science suggests two assumptions that underlie this research:

A1. For participants: The more fun a project is, the more motivated participants will be to continue or expand their participation.

A2. For outsiders: The more fun a project seems to be from an outside perspective, the more motivated outsiders will be to sign up and begin participating.

One powerful way to make mundane or difficult tasks engaging and fun is with games [12-14]. Games are a promising research topic within the field of education because of their potential to motivate students in sometimes difficult or repetitive learning tasks. In addition, games are also successfully employed for purposeful activities such as image tagging, identifying objects in images, and text recognition tasks [15-17]. A few citizen science projects successfully use games or game-like features to motivate participation. *Fold.it*, (http://www.fold.it) has participants play a downloadable puzzle game to simulate protein string folding. *Old Weather* (http://www.oldweather.org/) has participants assume a rank on turn-of-the-century warships, reading and digitally logging the weather reports from these ships. Participants can choose which ship to serve on and increase their rank as they become more involved in the project. Notably games in education, purposeful games, and citizen science games can include aspects of community, learning, and discovery within them.

In this research, we are particularly interested in games as a way to motivate and engage participants. Intrinsic and altruistic motivations also play an important role in most citizen science efforts, but these two variables are difficult to control, as they are internal to the participant's own interests and desires. Creating a fun and engaging user experiences, on the other hand, is something that the game design community has long practiced. Games may particularly benefit projects with topics not in the mainstream of “popular science,” where the content and theme of a purposeful game need not be highly related to the specific subject of scientific inquiry. Much useful information about the practice of creating motivating and engaging games across a vast spectrum of subjects and topics is available [e.g. 18]. Interest in games as motivators suggests several research questions:

RQ1. How can games or game-like features create a fun and motivating experience for participants?

Game design has been described as “creating experiences” for players [18], and many different kinds of game experiences are possible. Story-driven games, which feature plot, settings, and characters, have the potential to be highly motivating and enriching experiences. However, most purposeful gaming research deals with non-story games (e.g. Google's image labeler at http://images.google.com/imagelabeler/). Interest in exploring different kinds of motivational techniques in games suggests a new research question:

RQ2. How do story-driven game experiences for citizen science affect fun, motivation, and the user experience?

A possible challenge to using games as a motivator in the citizen science context is that games might compete with other motivations that participants bring to the project. Some users will have scientific or altruistic interests, and these users may not be as motivated by games. Some kinds of games might have the effect of diluting the information or experience that interests such users. Accordingly:

RQ3. How do games affect motivation for participants who have intrinsic or altruistic reasons to participate?

In addition, some participants bring their own expert knowledge to a project; games may interfere with their ability to share and use that knowledge in an effective and motivating manner:

RQ4. How do games impact the motivation of participants who have expertise in a project's specific field of inquiry?

C. Data Quality

Data quality is highly important to any citizen science project, and is a multi-dimensional construct consisting of a variety of attributes [19-21]. Data quality, as a side effect of crowdsourced scientific efforts, requires more study, but [22] describes an effort to compare novice field observations to expert observations, finding that observations between the two groups are comparable, with some disagreements between experts and novices. Study [23] is similar, verifying data quality in a marine invasive species project, and noting that participants in middle school were 95% accurate in their observations. This study also found that motivation had an impact on the completeness of the data set; some participants did not finish because of the tedious nature of the tasks.

A variety of researchers have explored the notion of data quality in other contexts, particular in an organizational sense. Orr [20] describes a simplistic measure for data quality, where a level of 100% indicates that a data set exactly matches the real world, while a level of 0% indicates that the data does not reflect the real world at all. Orr acknowledges that this simplistic measure is inadequate, suggesting that the accuracy, timeliness, and consistency of data are more important.

Pipino, Lee, and Wang [19] emphasize the multidimensional nature of data, and identify several measures of data quality: accessibility, appropriate amounts of data, believability, completeness, concise representation, consistent representation, ease of manipulation, freedom from error, interpretability, objectivity, relevancy, reputation, security, timeliness, understandability, and added value.

In this research, we adopt the data quality framework suggested by Wang and Strong [21], which is composed of four data quality attributes: 1) *intrinsic data quality*, the believability or accuracy of the data, 2) *contextual data quality*, how relevant, timely, and complete the data is, 3) *representational data quality*, how interpretable and easy to use the data is, and 4) *accessibility*, how easy the data is to access and use. Evaluating only the accuracy of data collected by a social-computational system is not adequate; we are also interested in the ways that system design can impact the contextual, representational, and accessibility qualities of the data.

Citizen science systems that favor games may have significant impacts on data quality. For example, participants who find games to be motivating may provide better or more data than those who do not. Participants who would prefer to participate through non-game interfaces may lose interest in games more quickly. The following research questions address participants, motivation, and data quality:

- RQ5. How do games for citizen science impact data quality for participants who lack intrinsic or altruistic motivation to participate?
- RQ6. How do games for citizen science impact data quality for participants who have intrinsic or altruistic motivation to participate?
- RQ7. How do games for citizen science impact data quality for participants who have expertise in the scientific subject of inquiry?

III. THE CITIZEN SORT PROJECT

Citizen Sort, currently under development, is a social-computational system for citizen science. It will consist of several key components, following a *system assemblage* approach, where overall project goals are accommodated by assembling different functionalities and technologies into a unified whole, with an eye toward satisfying user needs and motivating participation. *Citizen Sort* components will include a project website and various citizen science games.

A. Design Problem

The *Citizen Sort* project will address a challenging problem of importance to natural scientists in the ecology and conservation fields. Currently, many citizen science projects encourage participants to take photographs of wildlife and upload them for use in ecological research. Many people are also personally curious about plants, animals, and insects that they encounter. Identifying photographed species can be difficult, however, especially when identification must be made down to the species or sub-species level. Most species identification tasks require expert knowledge, as well as the use of complex taxonomic or matrix-based feature identification tables. Identification is usually tied to particular features and attributes (called “characters” and “states” in the ecological nomenclature). For example, a moth may be identified by its forewing color (character), with a red color (state) helping to indicate a particular family or genus or moth. Other than through time consuming expert review, there are few resources to accurately and swiftly identify submitted photographs.

The *Citizen Sort* system will support distributed cooperation of experts, non-experts, and computer systems in the task of accurately identifying the characters and states that enable classification of various species. This data will be of value to scientists who study particular plant, animal, or insect populations in various locations, and it will be of value to participants who are curious about plants, animals, and insects that they have encountered.

B. Research

Citizen Sort has both information science and natural science goals. The information science goal is to evaluate the role of motivation in citizen science and to explore the impact of various system design decisions on motivation and data quality. The natural science goal is to assist ecologists with an important and challenging classification task.

Citizen Sort participants will play games and use tools to help identify particular characters and states of a photographed species. For example, a game might ask a participant to select from a pool of images where a particular character state is observed, earning points for how rapidly the selection can be made. The data produced by such interactions will be compared to a gold standard which has already been classified by experts.

Developing and evaluating the *Citizen Sort* system, a real citizen science project with valid natural science goals, will help to explore the motivations of participants and data quality in a natural and realistic setting. Currently, three trial projects have been arranged: a moth classification project, a project to identify characters and states for the Caribbean Lizardfish, and a project to classify many species of invertebrates to the phylum or order level. Eventually, the *Citizen Sort* project may be expanded to classify other plants, animals, and insects, producing additional data and additional opportunities for information science research.

C. Design & Development

An interactive website will be the central information locus for the *Citizen Sort* project and will enable interested individuals to sign up and begin participating. Assumption 2 suggests that outsiders will be more motivated to join a project if it seems fun and engaging, so the *Citizen Sort* website will be designed around a rich graphical experience that ties the website tightly to the project's game offerings. The site will also include other fun elements such as participant scores, stats, and achievements. To evaluate the ways that design choices can motivate participation, it may be useful to present different groups of users with different website designs. This will afford comparative evaluations between game-like layouts and more traditional layouts.

The *Citizen Sort* project will have a variety of *interactions* as its centerpiece, so named because they feature one or more participants interacting with a data asset in various ways. In the case of *Citizen Sort*, photographs of moths, Lizardfish, and invertebrates will be the assets to be interacted with. Participants will use classification tools and games provided by the project to append new information (specifically, character and state information) to these assets.

RQ7 inquires whether expert participants may become de-motivated by games that downplay expert knowledge in favor of creating fun (but potentially trivial) interactions. Accordingly, *Citizen Sort* will feature several classification utilities that are not games. These tools will feature mechanisms that allow expert users to quickly apply their knowledge to the classification task. A variety of games will also be provided. Some will be simple classification mini-games in the tradition of current purposeful games; one game, feasibility allowing, will be a more elaborate, story-driven, gardening-style game that includes classification tasks as one aspect of game play.

The rationale for developing a complex, story-driven game is that some endogenous rewards, such as in-game money or prizes, may be highly motivating for certain participants, but only if they are available within a game world that endows them with value [18]. Furthermore, the ways that story and narrative can motivate participation or affect data quality in the context of citizen science is an interesting topic that has not yet been thoroughly explored.

Citizen Sort will be evaluated using a mixed methods approach, taking place through a combination of techniques and technologies. Usage patterns for the website and the various game and tool interactions will be collected and analyzed for insight into how participants go about using project resources. One possibility is to simply observe the decisions made by participants who are given no guidance as to which tools or games to use; this may be a useful way of determining which games are most or least motivating, or which kinds of users prefer which kinds of games. It may also be desirable to direct users to certain games or tools at different times, to measure different users' responses to the interaction experiences offered by *Citizen Sort.*

Some project components may be instrumented to provide additional layers of rich detail. For example, mini-games and the story-driven game will likely include data collection systems that can provide an aggregate view of who uses these games, their interests, and their patterns of use. Such sources of data can provide valuable information about sign-ups, retention, participant falloff, and most/least popular features and functionalities. This research program will also rely on qualitative sources of data, including open-ended surveys that may be issued at various times during a participants involvement in the *Citizen Sort* project, forum comments and suggestions, and interviews with selected participants. Data quality will be evaluated by comparison of collected data to gold standards, expert review, and interviews and discussions with users of the data.

Citizen Sort will be developed using a variety of standard web and multimedia technologies, including (X)HTML, CSS, and JavaScript. PHP has been selected for its potential to support dynamic web functionality. PHP and JavaScript may also be used for some classification utilities or mini-games. Adobe Flash, because it supports rich multimedia interactions, and because it is popular for much web-based game development, will be used for more ambitious interactive systems, particularly the story-driven game. Three developers and a lead designer are currently engaged in preliminary development tasks. An additional 6-7 developers will be hired to build out the *Citizen Sort* system as the project progresses.

IV. Discussion

Citizen Sort presents a variety of design and research-oriented challenges. Project scope is a major challenge, as it is for many design science research efforts. In [5], the need for multi-disciplinary expertise as well as expert developers is noted, and Galison [24] describes how such collaborations can be difficult when the needs and goals of different interested parties clash. *Citizen Sort* engages a number of disparate groups, including information scientists, natural scientists from a variety of ecological disciplines, software engineers, and web and multimedia designers.

Galison describes the idea of "trading zones" [24] to accommodate the needs of various collaborators through a negotiating process. *Citizen Sort's* lead designer takes a central role in these negotiations, acting as a coordinator between various groups, ensuring that natural science and information science requirements are balanced, and verifying that the project scope is feasible for the development team.

The scale and nature of the development task itself are additional important challenges. Game software can be highly complex to develop, as well as time consuming and difficult to balance and debug. While development on the scale of some multi-million dollar video games is not envisioned, it is still important to design game experiences that are professional in their presentation. Achieving a polished look is essential; poor presentation is an obvious but (from a research standpoint) not-very-interesting reason for a game to be de-motivating. We are primarily interested in how games motivate when the design of the game is of professional quality and reasonably well executed.

This is a particular challenge from a research standpoint because game development is not a purely scientific exercise. Professional game developers collect user data and do a great deal of empirical testing, but artistic sensibilities, instincts, and experience also play an important role [18]. One significant challenge for our project will be to maintain a high degree of rigor in our evaluation process and scientific conclusions while developing a social-computational system through design processes that may be subjective at times.

This is related to another important challenge: operationalizing the abstract concepts that we are interested in. While data quality has been deconstructed through the framework in [21] and can be operationalized in a variety of ways, including by measuring accuracy in relation to gold standards or by checking the completeness and usefulness of the data against science tasks or through evaluations by end users, notions of "fun" and "motivation" are more difficult to operationalize and measure. These concepts are multidimensional but not yet thoroughly understood, particularly in the context of citizen science. Furthermore, they are often subjective, with one individual finding fun in things that others would just as soon avoid. Identifying the dimensions of fun and motivation, and operationalizing these as measurable components of *Citizen Sort*, is an important goal of this research,

One possibility is to measure motivation through the relative popularity of various *Citizen Sort* games and features. For example, if one game is used more than another, we may be able to roughly claim that it is more fun or more motivating to use. However, this measure by itself is fairly crude. Comparison to another dimension, duration of play, may be useful. It may be possible to state that individuals who play one of our games for many weeks tend to find it more motivating or fun than those who play it just once, or we may determine that games where play sessions last for several hours are more fun or motivating than games where play sessions last just a few seconds.

Qualitative data sources will also improve upon the roughness of these measures. Participants will be asked about their motivations directly through surveys or interviews, before, during, and after play. Though self-reported data can sometimes be problematic on its own, *Citizen Sort* can be more thoroughly evaluated by triangulating many data sources. So, for example, website traffic data may be compared to data collected by instruments embedded in games. This will further be checked against survey results and forum posts. Of course, *Citizen Sort* participants must be made aware of the goals of this project when they begin participation, to avoid invading their privacy or betraying their trust.

V. CONCLUSION

Motivation and data quality are key aspects of citizen science that require further study. In this research, we look toward games as a method of motivating participation and exploring the nature of social-computation systems to support crowdsourced science. We eagerly anticipate further refinement of the ideas presented in this paper as the *Citizen Sort* system progresses from design concept to implementation and evaluation.

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