Enhancing Citizen Science: Building a Web-Based Platform for Optimizing the Area-of-Interest Data Collection Process

Yuvraj Lakhotia[1], Abdullahi Adeboye[2], Ryan Parsaee[3], Grace Valdez[4], Jeff Cheong[5], Benjamin Herschman[6]

NASA STEM Enhancement in Earth Science, Earth System Explorers, 2023

[1] Edison Academy Magnet School, 100 Technology Dr, Edison, NJ 08837. lakyuvraj@gmail.com
[2] Harmony School of Innovation, 13738 Old Richmond Rd, Sugar Land, TX 77498. abduladeboye@gmail.com
[3] Great Valley High School, 255 Phoenixville Pike, Malver, PA 1955. rparse06@gmail.com
[4] McCallum High School and Fine Arts Academy, 5600 Sunshine Dr, Austin, TX, 78756. gracenvaldez@gmail.com
[5] Temple City High School, 9501 Lemon Ave, Temple City, CA, 91780. jcheong123456@gmail.com
[6] Scheck Hillel Community School, 19000 Northeast 25th Ave, Miami, FL, 33180. benjaminherschman@gmail.com

ABSTRACT

Citizen science has emerged as a pivotal approach in expanding the horizons of scientific research on a global scale. A current study exemplifies the involvement of citizen scientists who create a virtual 3-kilometer by 3-kilometer grid, termed an Area of Interest (AOI), in their local surroundings. Within these AOIs, 37 evenly-spaced land cover observation points are generated using an external tool and conducted using the NASA-funded GLOBE Observer mobile app. However, participants have highlighted the inconvenience of navigating to the designated points within the AOI grid, posing challenges to their active engagement in the study. To address these concerns, we propose the development of an integrated web application that offers visualizations of the AOI points, ensures accessibility to each point, and facilitates seamless navigation to the locations in real-time. This project aims to present a comprehensive system that graphically plots a user's AOI points on an interactive map, leveraging the centroid location, empowering them to effortlessly complete the necessary observations at each point and keep track of these observations. By streamlining the AOI setup process and enhancing user experience, we envision broadening the accessibility of AOI observations and citizen science data to the wider public. The project will employ cross-platform frameworks, namely ASP .NET Core integrated with TypeScript and PostgreSQL, to expedite the development and deployment of the app on web-based systems. Validation and fine-tuning of the app's design will be conducted using previously-established AOI grids. The potential impact of this application encompasses enhanced user satisfaction, increased AOI creation rates, and reduced AOI setup and navigation times. These improvements can significantly contribute to the success of citizen science initiatives, fostering meaningful participation and high-quality data contributions from the open-science community.

Keywords: citizen science, accessibility, NASA, GLOBE, area-of-interest, web, application

RESEARCH QUESTION

This study aims to answer the following research questions: **Does this app succeed in optimizing AOI (area-of-interest) creation and increasing citizen scientists' comfort with the method in which these observations are taken? If it does, how does it hold up to the current system in place?** As citizen science grows in importance with regard to data collection, it has become more crucial to ensure applications used by citizen scientists are effective and easy to use. This research project aims to achieve just that, exploring our web application's ability to consistently create an accurate AOI based on previously input information, while ensuring users are satisfied with the app's ease-of-use.

1. INTRODUCTION

An AOI (area-of-interest) is a standardized data set that can create a high resolution model of an area's land cover ("Observation Stations"). This type of model is more efficient in its resolution compared to satellite imagery which cannot create such high-quality imagery data. Each AOI is mapped by a given set of coordinates, evenly spaced in a 3-kilometer by 3-kilometer square grid. Using the GLOBE Observer app (*GLOBE Observer*, 2019), which is the main instrument used to observe points on Earth, any given citizen scientist is able to record AOI observations. Users must classify each point by taking photos which are then uploaded to a NASA database. Our main premise is the need for accessibility of science, particularly for citizen scientists. This was based on our mentors, Russanne Low and Peder Nelson, who proposed the problem of the AOI that we currently have with the app. With the current revisions of the AOI that we would need to put in the data, it would be an exceedingly long process. This new AOI system we have developed would be able to add in more photos with scientists around the world. In addition, we have developed a web-based application that streamlines the data classification process in regards to the AOI procedure. The GLOBE Observer app has been difficult to navigate, especially for those not well-versed in earth-science practices. Such limitations also hinder the use of AOI classification for citizen science projects.

Citizen science projects hold significant importance in the scientific community (de Sherbinin, 2021). For instance, in 2017, citizen scientists using data from NASA's Kepler space telescope made an incredible find of five new exoplanets (*Kepler and K2 Missions*, 2019). Moreover, long-standing initiatives like the Audubon Society's Christmas Bird Count showcase the enduring impact of citizen science. These projects are vital due to their accessibility and contributions to scientific knowledge. Simplifying the process through innovations like the Automatic AOI app can enhance data collection efficiency and save time. Our research findings, presented later in this paper, demonstrate the app's potential benefits for citizen science efforts. Together, we aim to improve the landscape of citizen science and its impact on scientific discovery.

Overall, our main goal was to increase user access to instruments that make the data collection and classification process easier for citizen scientists.

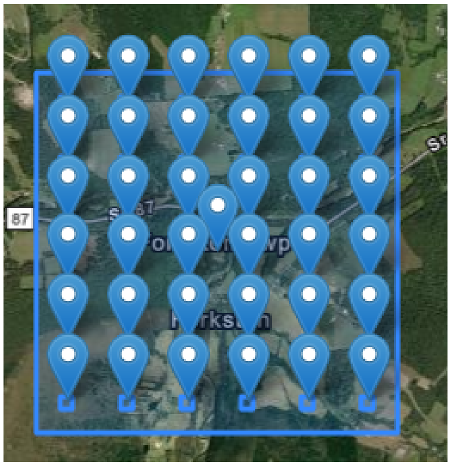

FIG. 1. Sample AOI created using the existing tool.

2. EXISTING PROCESS

2.1. Various Components

The current AOI process is split into three main parts: setup, collection, and classification; this project aims to optimize the first two. Integrating each component requires technical expertise, multiple devices, and a thorough understanding of the entire process. Each aspect of this unintegrated process further drives user dissatisfaction.

2.2. Setup Process

The current AOI grid setup process requires users to visit the "Create Sample Grid" page under the NASA Earth Science Education Collaborative website (*SEES2022–Create Sampling Grid*, n.d.). Here, users select the centroid location (center point of the grid) on an interactive map, which prompts the generation of the other 36 points. Users then export the list of points' latitude and longitude coordinates to a GeoJSON (*RFC 7946 - the GeoJSON Format*, n.d.) or CSV (Shafranovich, 2005) file for visualization in external tools such as ArcGIS (*Map Viewer*, n.d.). At present, this is the only way to identify observation points and their locations.

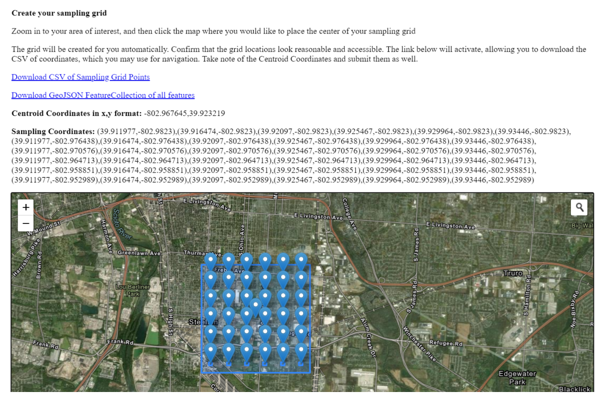

FIG. 2. "Create Sample Grid" page.

2.3. Collection Process

To collect data, users have to navigate on their own to each observation point and take photographs in each cardinal direction, up, and down. This process is done using the GLOBE Observer app on mobile devices. It is to be noted that the AOI grid visualization is difficult to view on mobile devices, hence users constantly have to refer to a navigation tool such as Google Maps.

latitude	*longitude*
29.65368	*-95.6207*
29.64244	*-95.6336*
29.64694	*-95.6336*
29.65143	*-95.6336*
29.65593	*-95.6336*
29.66043	*-95.6336*
29.66492	*-95.6336*

TABLE 2. Sample AOI grid (#7) CSV section in TX.

3. METHODOLOGY

3.1. Identifying Weaknesses in Existing System

Before starting our research, we first assessed the weakest aspects of the existing process to address in our limited time frame. In order to do so, we created a satisfaction survey that quantitatively measured users' opinions about the AOI process as a whole by asking an array of different questions. This survey, shared with all 52 interns on the Earth Systems Explorers team, included questions such as "How convenient was it to create your AOI?", "What additional features would you like to see in GLOBE Observer?", and "How likely are you to repeat this process." This gave us the information regarding the initial blueprint we needed to start developing our web app.

The survey revealed that as reported by our GLOBE Satisfaction Survey, over 80% of GLOBE interns answered above a 6 on the inconvenience scale, with a 1 being not inconvenient and a 10 being very inconvenient, and 66% of total interns would not repeat the AOI process. When presented with this data, it is quite clear that the current system tasked with the AOI process has fallen substandard.

3.2. Motivation Behind Research

We began this project due to personal experience as well as intern feedback. Most interns considered the AOI portion of the internship as one of the most frustrating aspects of the program as a whole. We decided that addressing this issue by developing an app tasked with streamlining the AOI process would not only make for a great research project, but also enhance the experience for future SEES interns. A more efficient and convenient app would encourage interns and volunteers to complete their datasets, providing crucial data to over 38,000 citizen scientists in the process (*GLOBE Impact and Metrics - GLOBE.gov*, 2022), as well as increasing land cover accessibility. Furthermore, this would bolster volunteer retention, as the AOI process would be less arduous and more convenient, prompting a greater number of returning users.

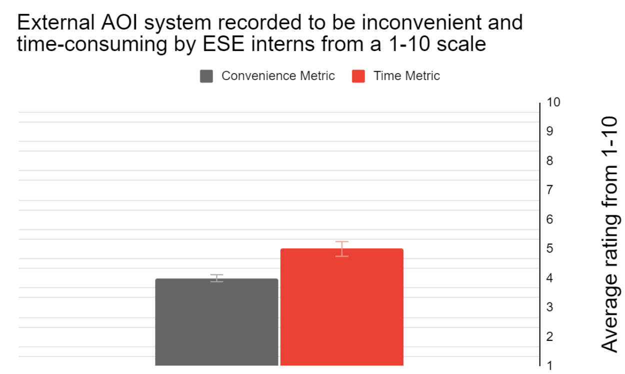

FIG. 3. Satisfaction Survey of over 50 interns.

3.3. Application Development Process

The new, integrated application targets four new features: associating user data/AOIs with a set of login credentials, implementing a tracking system for each observation point, providing a navigation system between points, and avoiding water or inaccessible areas. Serving as a "one-stop-shop" for all steps of the AOI creation and management process, the app required a strong foundation, more appealing user interface, and structured method of data storage. All these needs were met via ASP .NET Core (consisting mainly of C# and HTML/SASS), TypeScript for managing the map embed, and PostgreSQL to persist the data.

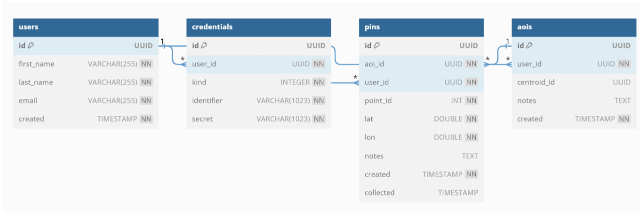

FIG. 4. App database structure diagram.

3.4. Creating a Login Portal

To ensure that users are able to retrieve their data after initially generating their AOI grid, it was important to implement a login/register system. This would allow the app to associate any updates to the map, AOI, or observation points with the correct user. With a simplistic design and uncomplicated fields, the sign-up and sign-in process will encourage further expansion of such citizen science missions.

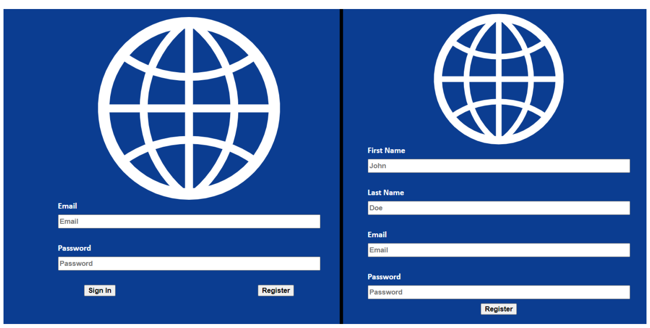

FIG. 5. Login and register pages.

3.5. Designing the Tracking System

With a set of nearly 37 points to collect, users often end up revisiting sites or miss out on some entirely. Our app's visualizations ensure that no point will be missed, with a clear, color-coded structure and unique numerical ID assignments. Upon collecting data from a point, users can simply check it off from under the "Pending" tab on the sidebar, which will change the pin color from red to green and transfer it to the "Completed" tab. Consequently, when the all 37 points are collected, the entire grid turns green, notifying the user that the AOI is complete.

FIG. 6. The main dashboard page.

3.6. Navigating Between Points

To decrease the amount of time users spend planning a brief excursion to some observation points, our app includes a navigation feature. Using the user's live location, this can suggest the *n* (user-inputted) nearest observation points and plot a round-trip spline route on the map. The navigation algorithm utilizes the haversine distance (Nichat, 2013) between the user and each point, along with a simple sort, to select the user-point pairs which have the smallest haversine value. The haversine formula calculates the distance between two points on a sphere (in this case, the Earth, which is almost spherical) given their latitudes and longitudes, as well as the radius of the sphere (used 6371.0710 km).

$$
\begin{aligned}
d &= 2r\arcsin\left(\sqrt{\operatorname{hav}(\varphi_2-\varphi_1)+(1-\operatorname{hav}(\varphi_1-\varphi_2)-\operatorname{hav}(\varphi_1+\varphi_2))\cdot\operatorname{hav}(\lambda_2-\lambda_1)}\right)\\
&= 2r\arcsin\left(\sqrt{\sin^2\left(\frac{\varphi_2-\varphi_1}{2}\right)+\left(1-\sin^2\left(\frac{\varphi_2-\varphi_1}{2}\right)-\sin^2\left(\frac{\varphi_2+\varphi_1}{2}\right)\right)\cdot\sin^2\left(\frac{\lambda_2-\lambda_1}{2}\right)}\right)\\
&= 2r\arcsin\left(\sqrt{\sin^2\left(\frac{\varphi_2-\varphi_1}{2}\right)+\cos\varphi_1\cdot\cos\varphi_2\cdot\sin^2\left(\frac{\lambda_2-\lambda_1}{2}\right)}\right).
\end{aligned}
$$

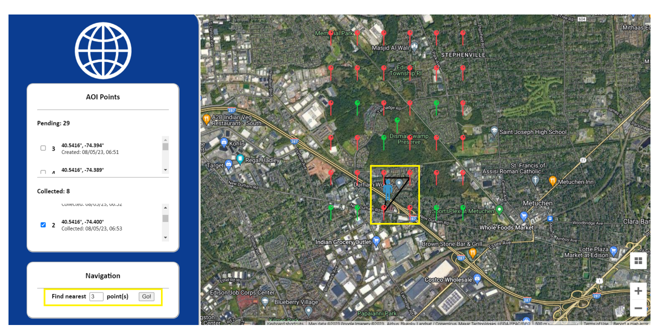

FIG. 7. Route to the nearest 3 pending points.

4. DISCUSSION

Our web app proved highly efficient when compared to the current system, with an 80% faster AOI creation process and 16.67% faster data collection despite having a group of volunteers inexperienced in the AOI creation process; this demonstrates our app's ease of use and efficiency in comparison with the current system.

Although our app did yield positive results in comparison to the current system in place, there are several limitations to the app. Firstly, unlike GLOBE Observer, the app we developed is a web app not a mobile app, hence it is limited in its adaptability and the number of different scenarios it can be used in (onsite, etc). We initially planned to adapt our web app to a mobile app but due to time constraints, we were not able to. Furthermore, data collection methods may not be accurate or consistent between volunteer observers. For example, due to the lack of an in-built navigation tool there may be discrepancies in travel time data. No navigation tool was specified, hence one group may have employed Google Maps as their navigation tool while the other employed Maps, which could have resulted in different routes and travel times. Observation time was also not specified which likely affected the data. One user specifically took observations for his first AOI at 7:34 AM on a Saturday and took the second at 5:23 PM on a Wednesday. The traffic situation was obviously different at those times and led to the experiment being less of a comparison between two systems and more of traffic and other scenarios playing an active role.

Similar platforms, like the ArcGIS (*Map Viewer*, n.d.) dashboard, employed the use of a built-in navigation system which gave step by step directions as well as a route to each selected point. While our app did not accomplish this feature, we decided to instead give a set number of points closest to the user based on the user's location.

There are a variety of improvements we hope to make given the time and resources. First and foremost, we would like to make a cross platform mobile app version of the web app we currently have, preferably for iOS and Android. This would enable it to be used in the field and across as many devices as possible. We would also like to improve our navigation system. Currently, the system simply gives a set number of points closest to the user based on their location, while we would like to keep this feature, we would also like to include a true navigation system similar to the ArcGIS (*Map Viewer*, n.d.) dashboard that creates a more organic path between points. Finally, we would like to implement an automatic avoid water tool. We currently have a "drag and drop" system in place that mainly serves this purpose where users can drag and drop pins manually to avoid water. However, this is essentially just a manual workaround, hence we aim to automate this process by including a feature where the app automatically detects if a point is on water and moves it a set number of pixels to the east, west, north or south until it is on land.

5. CONCLUSION

Our research highlights the exceptional efficiency of our web app when compared to the current system in place, improving upon it by as much as 80%. The mass adoption of our web app or a similar performing one could greatly improve the sheer amount of data citizen scientists have access to due to the faster and more efficient methods our app has in place. With less time spent on the field taking observations and more data, ranging from land cover to mosquitoes (*About - GLOBE Observer - GLOBE.gov*, n.d.), available to citizen scientists, the prediction of disasters such as wildfires, floods and landslides will increase tremendously.

Our results provide valuable insight for future research aimed at improving data collection for citizen scientists. In particular, a project aimed at creating an application designed to replace GLOBE Observer or serve as a helper tool would benefit from these results, combined with additional features such as an automatic image classification tool to achieve better results. Future work could also explore the addition of an automatic avoid water tool as well as integrate a larger data set in a more controlled environment for more consistent findings.

SOURCE CODE

The source code for the Automatic AOI application can be found at the following GitHub repository:
https://github.com/yuviji/SEES-Automatic-AOI.

A Google Maps API key was obtained for use in testing and demonstrating the application through the Google Cloud Console (*Google Cloud Platform*, n.d.) interface. The web-based application is built using ASP .NET Core 5.0 (wadepickett, n.d.) with TypeScript (*The Starting Point for Learning TypeScript*, n.d.) interoperability hosted locally using an Nginx web server. The user and AOI data is stored across various tables in a locally-hosted PostgreSQL database.

ACKNOWLEDGEMENTS

We would like to acknowledge and give thanks to our wonderful mentors Russanne Low, Peder Nelson, and Cassie Soeffing for pouring their hearts out into guiding us through this internship. We would also like to acknowledge our peer mentor, AJ Caesar for assisting us through this process, and mentor, Andrew Clark, for guidance on the AOI process. Additionally, we would like to thank our fellow Earth Systems Explorers interns and family and friends for contributing to our various experiments and providing us with the data needed for the project. Finally, this research project would not have been possible without the NASA Stem Enhancement in Earth Science (SEES) Internship program.

Yuvraj Lakhotia was the sole creator of the team's application, responsible for full-stack development of the web app which included writing over 25,000 lines of code, researching and implementing algorithms such as that which determines the n-closest locations to the user, and designing the application's user interface with HTML and CSS. Yuvraj also led the creation of the team's final research paper and authored the *Methodology, Source Code,* and *Existing Process* (Parts 3.3-3.6) sections of the paper.

Abdullahi Adeboye authored the *References, Research Question, Existing Process* (Parts 3.1-3.2), *Discussion, Conclusion,* and *Acknowledgments* sections of the final paper. He was also solely responsible for drafting an initial version of the paper which other team members referenced when completing their contributions to the final paper. Jointly with Jeff Cheong, Abdullahi also created the team's poster and registered the team for the AGU Fall Conference, while organizing communication with internship mentors in order to ensure that the team was fulfilling all expectations put forth by their mentors.

Ryan Parsaee created all graphical visualizations included in the final research paper, and oversaw both the human surveys and the analysis of the collected survey data which was included in the final research paper to demonstrate the application's efficacy. Ryan also led the creation of a PowerPoint presentation which was used in the team's video recorded presentation of their research project.

Grace Valdez contributed to the Introduction section of the final research paper and assisted in the completion of the *Conclusion*, *Methodology*, and *Discussion* sections. She also assisted in the creation of the PowerPoint presentation which was used in the team's video recorded presentation.

Jeff Cheong helped develop the team's initial plan for completion of the project, led the creation of the team's poster summarizing the final research paper, assisted in creating the PowerPoint presentation which was used in the team's video recorded presentation, assisted in authoring the *Abstract* section of the final research paper, and assisted in editing parts of the final research paper.

Benjamin Herschman was the sole creator of the project's thumbnail image, and he also designed the layout for the team's PowerPoint presentation which was used in the team's video recorded presentation. Benjamin assisted with editing the *Abstract* section of the final research paper and edited the team's poster.

REFERENCES

(1) *About - GLOBE Observer - GLOBE.gov*. (n.d.). Observer.globe.gov. https://observer.globe.gov/abouT

(2) *GLOBE Observer*. (2019). Globe.gov. https://observer.globe.gov/

(3) de Sherbinin Alex, Bowser Anne, Chuang Tyng-Ruey, Cooper Caren, Danielsen Finn, Edmunds Rorie, Elias Peter, Faustman Elaine, Hultquist Carolynne, Mondardini Rosy, Popescu Ioana, Shonowo Adenike, Sivakumar Kishore (2021). Citizen science is an important vehicle for democratizing science and promoting the goal of universal and equitable access to scientific data and information. The Critical Importance of Citizen Science Data, Frontiers in Climate vol.3, 10.3389/fclim.2021.650760, 2624-9553. https://www.frontiersin.org/articles/10.3389/fclim.2021.650760.

(4) *Kepler and K2 Missions*. (2019). NASA. https://www.nasa.gov/mission_pages/kepler/main/index.html.

(5) *SEES2022 - Create Sampling Grid*. (n.d.). Nesec.strategies.org. https://nesec.strategies.org/SEES2022_CreateSamplingGrid.html.

(6) *RFC 7946 - The GeoJSON Format*. (n.d.). Datatracker.ietf.org. https://datatracker.ietf.org/doc/html/rfc7946

(7) Shafranovich, Y. (2005, October 1). *Common Format and MIME Type for Comma-Separated Values (CSV) Files*. IETF. https://datatracker.ietf.org/doc/html/rfc4180

(8) *Map Viewer*. (n.d.). Igestrategies.maps.arcgis.com. Retrieved August 5, 2023, from https://igestrategies.maps.arcgis.com/apps/mapviewer/index.html.

(9) *GLOBE Impact and Metrics - GLOBE.gov*. (2022). Globe.gov. https://www.globe.gov/about/impact/globe-impact.

(10) Nichat, Mangesh. (2013). Landmark based shortest path detection by using A* Algorithm and Haversine Formula.

(11) *Google Cloud Platform*. (n.d.). Accounts.google.com. Retrieved August 6,

2023, from
https://console.cloud.google.com/apis/library/maps-backend.googleapis.com

(12) wadepickett. (n.d.). *ASP.NET documentation*. Learn.microsoft.com. Retrieved August 6, 2023, from https://learn.microsoft.com/en-us/aspnet/core/?view=aspnetcore-5.0.

(13) *The starting point for learning TypeScript*. (n.d.). Www.typescriptlang.org. https://www.typescriptlang.org/docs/.