Exploring the use of citizen science to process aerial photographs: challenges and next steps

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2016

Canadian Technical Report of
Fisheries and Aquatic Sciences 3165

Pêches et Océans Canada
Fisheries and Oceans Canada

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

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Exploring the use of citizen science to process aerial photographs: challenges and next steps

by

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Cat. No. Fs 97-6/3165E-PDF ISBN 978-0-660-05236-6 ISSN 1448-5379

Correct citation for this publication:

L.D. Burns, S.D. Petersen and S.H. Ferguson, 2016. Exploring the use of citizen science to process aerial photographs: challenges and next steps. Can. Tech. Rep. Fish. Aquat. Sci. 3165: vi + 11 p.

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Citizen science, the use of keen but untrained members of the public to assisting scientific research, is becoming an important field of scientific research. In recent years, rapidly developing technology has created new and more ways for citizens to become involved in the scientific community. The most recent advance has been in the gamification of data processing as a way to increase engagement and participation. Gamification is where users play games in order to process or contribute data for research projects. The High Arctic Cetacean Survey of 2013 resulted in a vast database of Arctic aerial images that need to be surveyed for cetacean life, a task that outstrips the capacity of the researchers conducting the survey. The large number of photos and the engaging subject of the photos (Arctic whales) provided an opportunity to design a game based platform to process images. A graduate student from Dalhousie University created a beta version of a game to sort through these photos, but it has not yet been brought to a full working version. Subsequently, a gap analysis was conducted to determine what development was needed to launch the game. We explore here the tasks needed to bring the game to its full use, outline challenges during development, and share recommendations for similar projects.

RÉSUMÉ

L.D. Burns, S.D. Petersen and S.H. Ferguson, 2016. Exploration de l' utilisation de la science des citoyens pour traiter les photographies aériennes: défis et prochaines étapes. Can. Tech. Rep. Fish. Aquat. Sci. 3165: vi + 11 p.

La science citoyenne, ou l'appel à des membres du public enthousiastes, mais non formés, pour contribuer la réalisation de recherches scientifique, devient un aspect important de la recherche scientifique. Au cours des dernières années, le développement rapide de la technologie a permis d'offrir aux citoyens des façons nouvelles et plus nombreuses de participer à la communauté scientifique. Le progrès le plus récent est la ludification du traitement des données comme moyen d'accroître la mobilisation et la participation. La ludification est le fait pour les utilisateurs de traiter ou de fournir des données en lien avec des projets de recherche en s'adonnant à des jeux. L'Inventaire des cétacés dans l'Extrême-Arctique de 2013 a abouti à la création d'une vaste base de données d'images aériennes de l'Arctique qui doivent être examinées pour y relever les signes d'activité des cétacés, une tâche qui dépasse les capacités des chercheurs qui procèdent à l'inventaire. Le grand nombre de photos et leur thème enthousiasmant (les baleines de l'Arctique) offraient l'occasion de concevoir une plateforme de jeu pour le traitement des images. Un étudiant diplômé de l'Université Dalhousie a créé la version bêta d'un jeu permettant de trier ces photos, mais la version de travail fonctionnelle n'existe pas encore. Par la suite, une analyse de l'écart a été réalisée pour déterminer quel développement requérait le lancement du jeu. Nous examinons ici les tâches requises pour aboutir à la version pleinement utilisable du jeu, pour décrire sommairement les difficultés rencontrées au cours du développement et pour faire part de recommandations pour des projets similaires.

INTRODUCTION

Citizen science is a term used to describe the collaboration between researchers and the general public on the gathering, analyzing, and evaluating of data for scientific research projects (Curtis, 2014). These collaborations take advantage of the general public's interest in the natural world, the greater number of citizens than scientists, and the bottleneck that can occur in a research project during the data collection or processing phase (Bonney et al., 2014). The history of citizen science reaches back to the amateur naturalists of the 1900s; however, only in recent years has the approach gained widespread use. Many of these projects use a network of observers to monitor specific species, for example, Monarch Watch (www.monarchwatch.org) tracks continental migrations of Monarch Butterflies (*Danaus plexippus*) or the famous Audubon Christmas bird count, which has been running since 1900 (Bock & Root, 1981). These projects gather the power of interested people who may have little training in the field to collect data from a wide geographical area. Projects that involve the public have the potential to increase productivity (Danielsen et al., 2010), corroborate models (Darg et al., 2011), and widen the scope of people who are engaged in the scientific process by allowing people without a background or formal science training to participate in authentic research (Kelling et al., 2009).

Citizen science projects enable researchers to collect more data through the participants then they could have potentially collected on their own, and technological advancements in sensing equipment and personal computers have made scientific research faster, more accurate, and more accessible to the public (Willett et al., 2010). This increased ability to collect more data in more accurate ways leads to large quantities of data that need to be sorted and analyzed, which can outstrip the capabilities of the research team. As techniques and technologies to collect data in biological research continue to improve, new and efficient means of analyzing these large data sets are necessary to make useful scientific conclusions (Kelling et al., 2009).

Fortunately, citizen science can be used not only to aid in data collection, but also to help manage and analyze large quantities of data. Recently, 'virtual citizen science' has taken advantage of the vast number of people worldwide with access to the internet (Kostadinova, 2011) to aid in scientific research remotely. Online projects have been developed that tap into the millions of internet users to analyze very large and complex data sets (Reed et al., 2012). An emerging form of virtual citizen science is using gamification, the application of game-related processes, to non-game activities and situations (Shea, 2014). In citizen science, gamification of data sets can utilize participants to sort, collect, and analyze data for projects. Digital gaming is a multi-billion-dollar industry and continues to grow as it becomes a common activity in many people's lives (Chambers et al., 2010). Scientific research requires challenges, choice making, and conflict, which are all ideal qualities for an online game to be built around, making the gamification of science research relatively easy (Sandbrook et al., 2014). Elements of gaming such as competition, social networking, and performance rating can be used to encourage citizen science participants to continue contributing, increasing data output from users (Everleigh, 2013). One of the first, and perhaps the most famous and productive citizen science game is 'Foldit', developed by the University of Washington. Foldit (www.fold.it) is an online game that harnesses the collective problem solving of users to uncover the 3D nature of protein folding. The participation of online Foldit users has led to publications, advanced algorithms for predicting protein structures, and solving complex protein structures that experts had yet been able to understand (Curtis, 2014). This project has been praised as a huge success and has been credited with making science accessible to the masses online.

Other science disciplines besides cellular and molecular biology have used gamification with success, and the potential gamification of other projects, especially those with high demands for person hours (Greenhill et al. 2014). The analysis of aerial survey imagery is one application that may be appropriate for data processing using gamification.

METHODS

DATA COLLECTION

Fisheries and Oceans Canada (DFO) performs regular aerial surveys to monitor a variety of marine mammal species. These surveys use visual observers to count and classify animals but increasingly they also carry photographic equipment to digitally record the flight path. For example, in recent years, all transects for Arctic seals in western Hudson Bay have aimed for full photographic coverage. More recently, transect lines with aggregations of narwhal and beluga whales have also been aerial photographed to aid in counting when animals are in high density or highly aggregated (Doniol-Valcrose et al. 2015).

The High Arctic Cetacean Survey (HACS) took place in August of 2013, and was the DFO's largest scale assessment of cetacean populations in the Canadian Arctic to date. The rationale behind the project was to obtain abundance estimates for narwhal (*Monodon monoceros)*, beluga (*Delphinapterus leucus*), and bowhead whale (*Balaena mysticetus)* populations that inhabit the Canadian High Arctic during the open water season. The survey was conducted using teams in three concurrent flying deHavilland twin otter 300 aircraft, each with two belly-mounted cameras to provide continuous photographic coverage. In total, approximately 6 terabytes of digital photographs were collected. Two of the five narwhal stocks were analyzed (85,727 photos) using two photo-interpreters to provide a comparison of narwhal abundance estimates using photos versus visual survey (Marcoux et al. 2016 in press) at a cost of approximately $80,000.

A sample aerial image can be seen in Figure 1. Transects were conducted at 1000 feet elevation (305 meters), and in total, over 241 hours of flying time was recorded.

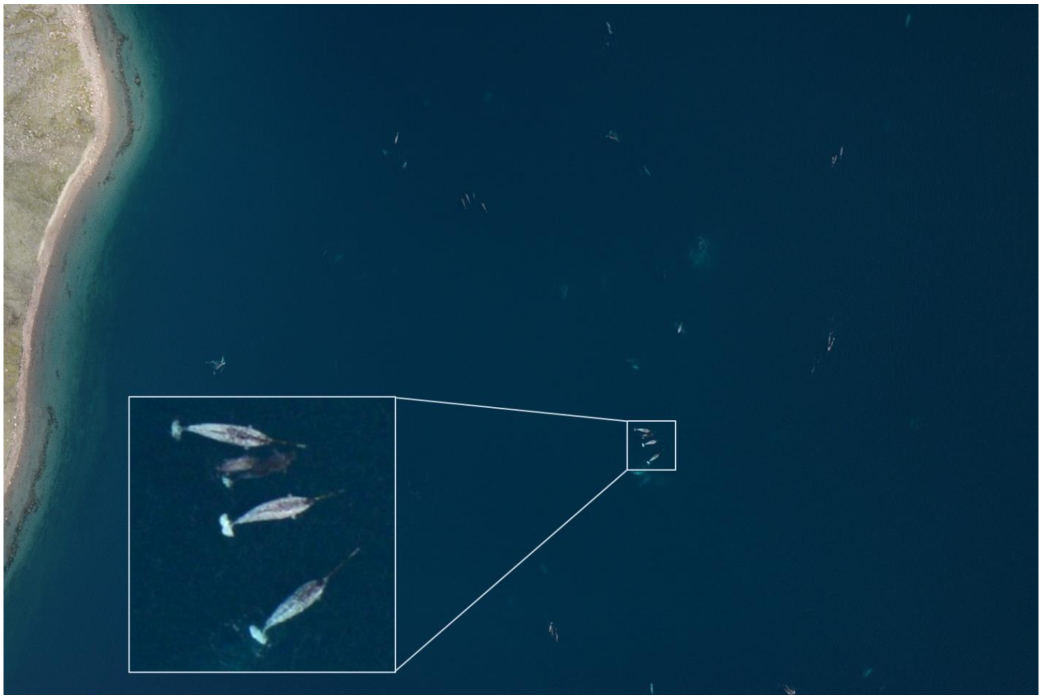

Figure 1. Example photograph taken on the High Arctic Cetacean Survey depicting narwhals (*Monodon monoceros)* in Tremblay Sound with zoomed detail showing three tusked males and a female with calf.

DATA ANALYSIS – GAME DEVELOPMENT

SPERA 2013 - 2014

The development of a platform in which to analyze the images from the HACS was first prepared by a Master's student at Dalhousie University (Raza, 2013). The student developed a web-based game that could be used at the Assiniboine Park Zoo (APZ, Winnipeg, MB) and online that requires participants to successfully pass through three levels of testing/ data processing to complete the game. At the start they are given a short instruction tutorial (Figure 2) after which they are asked a question that applies to the photographs that they will see. In the first level they are asked to find and mark all animals, regardless of species. Participants are then shown a series of photos, which have been seeded with a number of known or previously classified photos. In order to pass to the next level, participants need to successfully identify all photos with animals in the known set (and be 80% or more accurate on the number of individual in each photo) and in the process they will screen a number of new photos. If they are successful they will pass to the second level that asks them to find all whales (or another group that the researcher defines) and again they are presented with known and unknown images. In this level the unknowns are images from level one that other users have indicated contain an animal or animals. In the final step participants are asked to find and record all the species of whale (they are randomly assigned narwhal, beluga, or bowhead). The final output is a data file of: photograph ID number, with number, species, and location (on the photo) data. Validation of the data output is conducted internally by having multiple viewers score each photo before it is passed to the next level (contains animals) or discarded (no animals identified). The final set of photos is also externally validated by having select volunteer expert observers review the images. This internal and external validation should create a robust system.

Figure 2. Screen capture of the instruction screen from the web game created by the graduate student at Dalhousie University. The game is designed to have internet users search high arctic aerial images for evidence of mammalian life in order to help process the large quantity of images.

The final product of the game met much of the criteria that is needed to examine a data set of this nature. It was capable of adjusting the number of photos being examined, populated the games with correct numbers of known photos and successfully determined the number of times a photo should be shown to users before discarding or promoting the image to the next round. It also provided functionality to add new datasets to the game.

The game remained in beta testing stage upon the student's graduation. APZ purchased one large format tablet style computer and recruited volunteers to test the beta version of the game. The volunteer feedback indicated that the game needed to load and display photos faster, be made more user-friendly, and have clearer instruction and more tutorials before being released in its final version.

SPERA 2014 - 2016

Upon completion of the Master's project, attempts were made to find a computer science collaborator to complete the game, as personnel involved in the project did not have technical programming skills required to undertake the task. Unfortunately, a suitable collaborator was unable to be identified. Efforts to contract the build for a functional game also ran into challenges in the contracting stage. It was determined that given the unknowns related to computer science, game design, and game hosting needed to complete the game, a gap analysis was needed. In 2014, the software consulting firm Protegra was hired to complete a report on the current state of the game, in which they assessed the beta version and suggested what financial and technical commitments would be needed to bring the game to full usability (Watson, 2015).

This gap analysis identified several problems with the current version of the web game, with varying degrees of importance. Major technical problems identified were errors in coding and database use as well as security issues with the administrator's database. There were many instances of duplicated coding and different coding languages used throughout the program as opposed to one standardized language. As the web program currently stands, there is no password protection of the database, and it is hosted on the University of Dalhousie servers, which is not a viable long term hosting service, as it could be removed at any time. The speed of the game was also noted as problematic, and this was primarily attributed to the size of the images that required loading at the start of the game. An improved method of animal marking on the images was suggested, using a circle instead of a solid shape that covers up the animal after marking, and links the location to the image, not the screen, so zooming in to full resolution would not be an issue.

On a superficial level, Protegra noted that the visual appeal of the game could be improved upon, using more engaging fonts and colours, as well as addressing the image-scaling problem with the current viewing format. One of the important suggestions to improve the game is to add feedback at the end of each level to let the user know how well they had done in their task, which would make the experience feel more game-like.

Four options for the future of the game platform were explored by Protegra: (1) abandon the game interface entirely, (2) continue building on the existing game, (3) re-write the game in PHP language, or (4) rewrite the game in

.Net language. Option 1 is not recommended as there is currently no reasonable automated alternative to finding animals within the photos, but option 2 is also not recommended, as the code would need to be mostly rewritten in order for the game to function properly, which may take longer than starting a new game. Of option 3 and 4, re-writing the game in .Net is recommended, as it will be easier to find developers in this language and to maintain the game into the future. It will also cost the typical market rate if you were to hire developers externally, as .Net is a standard framework. The gap analysis concluded that if the game were to be written in .Net, it would take a senior programmer approximately 63 working days to take the game to its fully operational stage. This work was quoted (in 2015) as approximately 60K, which does not include additional game phase developing, web hosting, game maintenance, or user engagement.

DISCUSSION

There remains much potential to engage citizen scientists in the processing of large aerial photo databases such as that created by the 2013 HACS. Despite the challenges the project has faced, important opportunities exist to learn from this process.

A challenge with the HACS data and photographic aerial surveys in general is that the number of photographs taken over transect lines outstrips the capacity of the research group to manually analyze them. These challenges will likely increase as the technology for taking aerial photographs improves either through the use of Unmanned Aerial Systems (UAVs) or satellite imagery. In the HACS, the photographic transects resulted in hundreds of thousands of images that need to be processed. It is because of this massive amount of images that the plan to create a citizen science online game for analysis was undertaken.

Another challenge that became apparent over the course of the project was that the expertise of the researchers interested in the data did not overlap with the expertise needed to develop a computer game. If the project were to be continued with the intention of developing an online platform or an “app”, a collaboration of researching computer scientists (i.e., a post-secondary institution and students) would be an ideal partnership. This would add much needed expertise and resources to the team and potentially circumvent some of the development cost by recruiting student and interns. If this could not be arranged, a much larger budget would be required. This project encountered significant time delays and challenges identifying appropriate contractors within the Standing Offer list available to Federal departments for this type of work. Collaboration with researchers at a post-secondary institution is likely to take longer but at a much lower cost.

Many citizen science projects that require participants to analyze data encounter the problem associated with either hosting the materials on the internet or associated with the costs and ease of uploading/ downloading and storing large amounts of data. This is a particularly important consideration for the HACS, as there is a large number (257 756) of high quality images (~24MB each). The management of this volume of data will require improved data management and storage means (Newman et al., 2013). As cloud based data hosting improves, as well as processing speed of web browsers and mobile apps, this issue may resolve itself but still will need to be factored into the project costs. Currently, the entire HACS image dataset is over 5190 GB of data and the cost of hosting these large files will be substantial. If the game attracts a large number of participants (which will be necessary to assess all of the images), the downloading of images could be a burden for both the server and the user. User download speed and bandwidth caps are of particular concern for northern Canadian communities, who would be a targeted group for participation. These data caps could potentially deter them from using the game entirely. Strategies to reduce the amount of data to be analyzed could include implementing an automated pre-processing algorithm that would remove certain photos from the database (i.e., those with high glare, or that are all land or ice). Another possibility is to have an automated algorithm that detects potential whales and then provide the gamers with photos that likely have whales and ask them to identify if they are real whales of not. In addition, cropping images to reduce the transect width may be a viable alternative option to reduce upload/download and storage costs as well as increase loading speed. Whatever the strategy, significant thought needs to be given to this aspect of the project.

Alternative to both an institutional collaboration and independent programming contractors would be to use a pre-established online tool and community that specializes in citizen science web based games. The most well know of these is the Zooniverse project (www.zooniverse.org), which develops online interfaces for researchers to present raw data to the public in a format that can be analyzed. In late 2013, Zooniverse surpassed one million volunteers participating in over 20 projects that range from humanities, to astronomy, to biology. Once an interface is developed, Zooniverse invites internet users to participate until the project is complete. This generally provides thousands of person hours worth of processing time in a short time frame. Zooniverse provides this platform at no cost to the research team. Recent advances in this platform include the ability for researcher to design their own citizen science project.

A highly appealing part of the Zooniverse service would be the core group of users that the website brings with it. Citizen scientists worldwide already visit the site regularly, which would bring exposure to the project. Zooniverse selects projects to be displayed on their featured projects page based on similarity to other current projects and interest level, and there are currently other wildlife camera trap projects, but nothing involving the Arctic or aerial imaging. This would likely make the HACS photo data unique and appealing for their featured project main page. However, using the service would have some drawbacks that should be considered, which are mainly centered around the vast number and file size of aerial images that need to be sorted and analyzed. There is a 100GB and 10,000 item limit to photo upload and storage, although it is possible to package the data in to sets. There is contact information given to request more storage size if needed. Even so, it is likely that the images from the survey would need to be cropped or divided to keep storage size down. The other shortcoming of Zooniverse is less control over the interface. For example, creating a game such as the beta version is not possible and simple actions such as being able to “zoom” into images, is not currently supported. Regardless of the method in which the game is completed, when the it is finalized and put online (or locally hosted at the APZ), time for fielding questions and comments from citizen scientists should be factored into projected staffing costs, as it is often underestimated how many person hours it can take to manage users (Curtis, 2014). However, this has also been described by researchers in Curtis (2014) as one of the most rewarding aspects of running a virtual citizen science project.

When deciding on the future direction of the project, or redevelopment of the project, it will also be important to consider the communication strategy needed to recruit participants. If a new program is created, there needs to be equal consideration for initially attracting users as well as ensuring quality data output from the users. In this respect, partnering with zoological institutions would be ideal as visitors already have an interest in biology, research, Arctic species, and often, public participation in science.

The analysis of the images obtained in the HACS is a large task that currently outstrips the capacity of researchers, but with the use of an online citizen science game, members of the general public could be used to outsource the data sorting. While this task of creating a game has not been completed, much potential remains in the use of games to aid in this project as well as scientific research in general, whether through an online network or specially designed programs.

FUTURE RECOMMENDATIONS

1. Look for collaboration opportunities with organizations or individuals with computer science, database management, and game development expertise, such as a post-secondary institution.

2. Explore strategies to reduce file size or number of files needing processing, including image cropping and resizing, and explore data hosting options.

3. Allow appropriate timeline to approve collaborators and budget for game creation and maintenance.

4. Target the best audience for the game with effective communication plan. For the HACS data, a locally hosted game at the Assiniboine Park Zoo could be effective.

5. Plan for technical maintenance of game and database, as well as fielding questions from game users.

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