On the Effectiveness of Crowd Sourcing Avian Nesting Video Analysis at Wildlife@Home

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Abstract

Wildlife@Home is citizen science project developed to provide wildlife biologists a way to swiftly analyze the massive quantities of data that they can amass during video surveillance studies. The project has been active for two years, with over 200 volunteers who have participated in providing observations through a web interface where they can stream video and report the occurrences of various events within that video. Wildlife@Home is currently analyzing avian nesting video from three species: Sharptailed-Grouse (*Tympanuchus phasianellus*) an indicator species which plays a role in determining the effect of North Dakota's oil development on the local wildlife, Interior Least Tern (*Sternula antillarum*) a federally listed endangered species, and Piping Plover (*Charadrius Melodus*) a federally listed threatened species. Video comes from 105 grouse, 61 plover and 37 tern nests from multiple nesting seasons, and consists of over 85,000 hours (13 terabytes) of 24/7 uncontrolled outdoor surveillance video. This work describes the infrastructure supporting this citizen science project, and examines the effectiveness of two different interfaces for crowd sourcing: a simpler interface where users watch short clips of video and report if an event occurred within that video, and a more involved interface where volunteers can watch entire videos and provide detailed event information including beginning and ending times for events. User observations are compared against expert observations made by wildlife biology research assistants, and are shown to be quite effective given strategies used in the project to promote accuracy and correctness.

Keywords: Citizen Science, Crowd Sourcing, Video Analysis, Wildlife Ecology, Big Data

1 Introduction

Cameras have become popular tools in the field of avian ecology as they can dramatically reduce researcher impacts on behavior and monitor animals in remote locations [3, 5]. However, many

Figure 1: A sharp-tailed grouse in day, dusk and night conditions (top), and a piping plover in varying light conditions (bottom). Birds are circled in red. Given the cryptic coloration of the bird and lighting conditions, it can be very difficult to distinguish the bird from a rock, grass or other objects.

of these studies have been hampered by small sample sizes, where few have studied more than 100 nests [5], limiting the biological inferences that could be made due to these limited sample sizes. Part of this limitation is due to the lack of tools to swiftly analyze large amounts of video footage. In the summers of 2012 and 2013, numerous cameras were set up across western North Dakota, gathering over 35,000 hours of video footage of sharp-tailed grouse (*Tympanuchus phasianellus*), approximately 6 terabytes of data. In addition, 20,000 hours of video has been gathered for interior least tern (*Sternula antillarum*), a federally endangered species, and 30,000 hours for piping plover (*Charadrius melodus*), a federally threatened species. There are plans to monitor these birds in future nesting seasons, which should result in another 30,000 hours of video. The sharp-tailed grouse is considered an *indicator species*, meaning that the success of the species is closely tied to the health of the wildlife in the area. An analysis of this video will not only result in a wealth of biological knowledge about these species, but can also be used to examine the impacts of oil development in western North Dakota.

There are significant challenges detecting the presence of birds and events of interest within this wildlife video (see Figure 1). The species being studied, along with many of their predators, have evolved with *cryptic coloration*, or camouflage, which makes it difficult to distinguish them from their surroundings. Further, the video is taken from uncontrolled outdoor settings, with vegetation moving in the wind and changing weather conditions. Footage is recorded continuously with daytime video captured in color. Infrared light emitting diodes (LEDs) are used in low light and night conditions and recordings during this time are in black and white. This results in a wide variety of video quality and color.

Wildlife@Home has been developed as a citizen science project to recruit the help of public volunteers in this analysis, to detect events of biological interest within the video. The end goal is not to simply have the public aid in watching this video, but rather to take these observations and create a robust human-annotated data set which can be used to develop and evaluate computer vision methods for automated analysis of this video – which stands to greatly benefit the biological community. Wildlife@Home has been active for two years, with over 200 volunteers having participated in watching avian nesting video. This work presents recent work updating the crowd sourcing interface which has resulted in significant improvements in the accuracy of user observations, while at the same time dramatically reducing storage needs.

2 Related Work

Crowd sourcing has been successfully used by citizen science projects to tackle problems requiring human feedback. GalaxyZoo [8, 7] has had great success in using volunteers to classify galaxies in images from the Sloan Digital Sky Survey [1]; and PlanetHunters [6] has been used to identify planet candidates in the NASA Kepler public release data. More recently, Snapshot Serengeti [9] has been created to classify images from camera traps in the Serengeti National Park. However, these projects focus on volunteers doing identification and classification of images, not video.

In avian ecology, Cornell's NestCams project [2] has provided an outstanding resource for environmental education and gained popularity through the use of nest cameras to attract the public's interest in environmental science. NestCams primarily focuses on public outreach where video is collected opportunistically from cameras installed in bird houses, capturing a variety of cavity-nesting species. The CamClickr project has sparked applications of nest video archives for education in collegiate-level animal behavior courses [10]. More recently, eBird [11] is a citizen science project which allows users to upload observations of birds through handheld devices, providing spatio-temporal information about the bird distribution and abundance.

To our knowledge, Wildlife@Home is the only citizen science project which deals with classifying large volumes of video data, and is unique in that the volunteers are actively involved in providing scientific results from their observations.

3 Wildlife@Home Infrastructure and Interfaces

3.1 Data Collection

The nest cameras used to gather this avian nesting video store video in 300 MB AVI files, which are encoded with the H264 codec. This means while the files are of fixed sizes (apart from the last taken from a camera when videos are gathered), they are of varying times depending on compressed the files were. On average videos are around 53 minutes long, but can reach times of up to 11 hours when there is little to no movement or the video is very dark at night. Every 4-5 days per nest, the SIM cards are swapped out (as the camera sites are too remote for wireless transmission, and wireless transmission also requires too much power) and then this video is uploaded to the Wildlife@Home video server.

3.2 Hardware and Software Infrastructure

The video data for Wildlife@Home is stored on a shared Dell NSS-HA storage appliance with 144 terabytes (TB) in RAID 6 configuration for 110TB usable storage utilizing the Red Hat Enterprise Linux XFS file system. This storage system is mounted on the Wildlife@Home video server which handles the conversion of the archival video to formats required for HTML5 streaming (OGV and MP4), as well as serving the video to crowd sourcing webpages and clients for volunteer computing. The video server also hosts the database which keeps track of video information and user observations. A third server handles all webpages for the Wildlife@Home project and the database user information and volunteer computing. This infrasructure is presented in detail in Desell *et al.* [4].

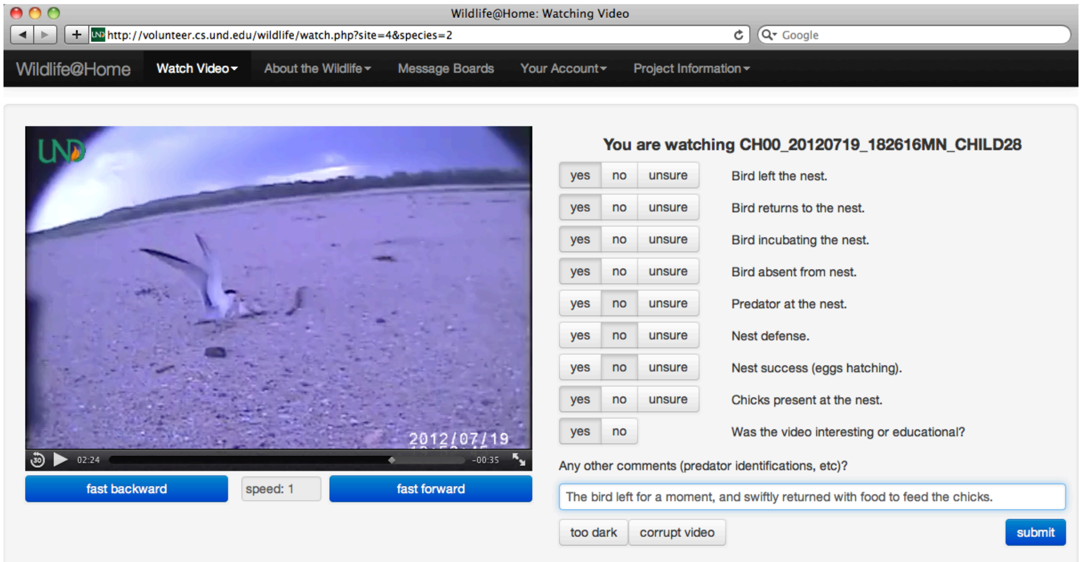

Figure 2: An example of the original interface used for crowd sourcing. The page has been developed using HTML5, jQuery and Bootstrap, allowing for easy use across different devices and web browsers. Users are shown 3, 5, 10 or 20 minute clips, and can select yes, no, or unsure for if any of a set of events occur within the video.

Wildlife@Home has gone through two iterations of crowd sourcing interfaces, which are described in Sections 3.3 and 3.4. The change to the new interface was motivated by a number of reasons, including user feed back, quality of information being generated (examined in Section 4), and simpler infrastructure requirements.

3.3 Original Interface

Figure 2 shows the original interface, where users were asked to mark yes, no or unsure to eight different categories about bird behavior: 1) a bird leaves the nest during the video, 2) a bird returns to the nest during the video, 3) a bird is present in any frame of video, 4) a bird is absent in any frame of the video, 5) a predator is in the video, 6) a bird defends the nest in the video, 7) chicks hatch in the video, and 8) chicks are present in the video. A user could also report if a video was corrupt, too dark, or interesting. Initially, video segments of 3 minute durations where shown to the users, and later 5, 10 and 20 minute durations were shown in response to users having difficulty determining sharptailed grouse presence in the shorter videos.

3.4 New Interface

While the original interface was relatively simple and easy to use, it added additional data requirements. The archival AVI data was already required to be stored, along with converted full length videos in OGV and MP4 format for streaming to the expert video observation interface. Those full length videos then also needed to be split into segments in both OGV and MP4 formats for viewing on this crowd sourcing interface. This meant that for each video, 4 additional copies of that video, two for full length and two for each split length duration video segment were required. With a total of 10.7 TB of archival video already gathered, and even

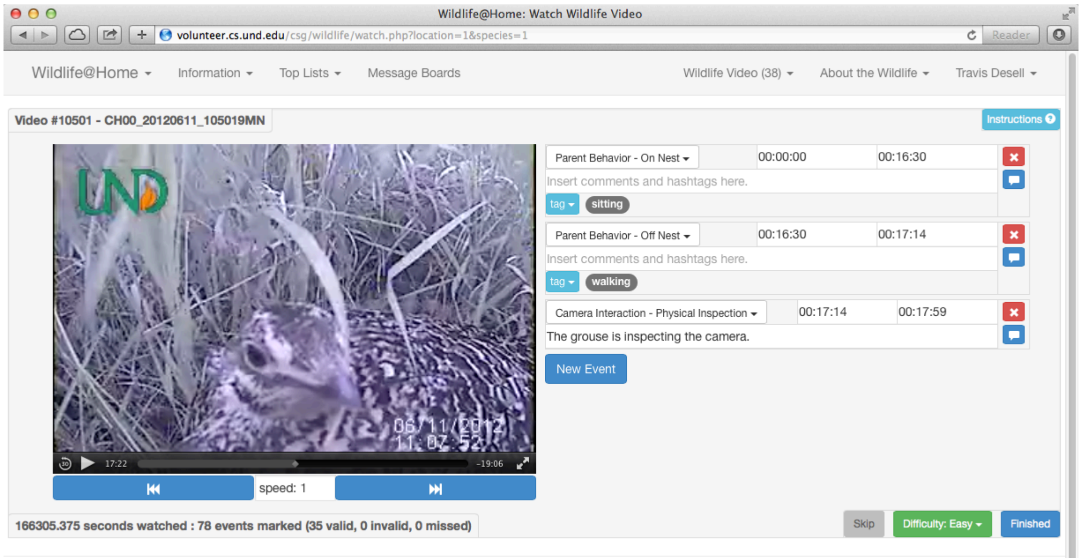

Figure 3: An example of the new interface used for crowd sourcing. Users are shown entire videos instead of short clips, and can specify the start and end time for a large number of events, and provide tags and comments for additional detail. Users can also specify how difficult it was to determine events for the video.

more expected from future field seasons, the additional space requirements for the split video segments became excessive.

When the expert interface was completed, due to the volunteer's requests for longer videos along with poor performance given what users could determine from the short the video segments (see Section 4.1) and space issues, the more advanced expert interface was used to replace the original interface, shown in Figure 3. In this interface, users have a significantly wider range of events to classify within videos. 25 different events could be classified by users, from the following 7 categories:

- **Parent Behavior**: *Not in the video*, *on the nest*, *off the nest*, and for piping plover and least terns only (given that they are bi-parental nesting birds), *foraging* for food, *adult feeding adult*, and *parent feeding chicks*.
- **Parent Care**: *Brooding chicks*, *removing eggshells*, and for piping plover and least terns only *exchanging nesting duties*.
- **Chick Behavior**: *Eggs hatching*, *chicks in video*, and for piping plover and least terns only *chicks foraging* and *chicks acting submissive*.
- **Territorial**: *Human in video*, *non-predator animal in video*, *predator in video*, and *nest defense*.
- **Camera Interaction**: Sometimes the birds inspect or interact with the nest cameras. These can be either a *non-physical observation*, *physical interaction*, or *agressive attack*.
- **Miscellaneous**: Users have the option to enter additional *unspecified* events.
- **Error**: Given the large amount of data collected and the uncontrolled outdoor settings, various errors can occur such as *camera issues* wher the camera gets knocked over, *video errors* where the video file is corrupted, and the video being *too dark* in some night time conditions.

Duration (s)	Completed	Observations	Valid	Invalid	Inconvclusive	Valid (%)
< 180	89,645	220,320	206,193	13,129	618	93.58
181 ... 300	8,942	18,715	17,930	649	75	95.80
301 ... 600	6,446	14,022	12,899	1,033	50	91.99
601 ... 1200	3,785	8,396	7,569	744	55	90.15
Total	108,818	261,453	244,591	15,555	798	93.55

Table 1: Performance of volunteers based on varying video durations for the original interface. Duration ranges are in seconds.

This interface allows user to enter any number of events, specify the start and end time of the event along with comments and tags for further detail. By clicking the discuss button to the right of an event, a forum post will be generated for the user to allow them to discuss the section of a video specified by that event in the Wildlife@Home forums with other users and project experts. Users can also specify how difficult it was to provide events for that video. When a user is finished, the interface will provide options for the user to either view the next video from that nest, or to randomly select a new video. In addition to reducing space requirements, this new interface also makes direct comparison of volunteer results to those made by the project's experts.

4 Results

4.1 Original Interface

Results for the original interface were gathered over a period of 9 months, from August 2013 to April 2014. 206 users provided 261,453 observations for 108,818 video segments, meaning on average it took approximately 2.4 views to reach a quorum for a video segment. These 261,453 observations total over 7,411.2 hours of video watched by volunteers. Of these observations, only 798 were marked inconclusive, and 15,555 marked invalid. In the later months of the original interface, video segments were also generated with durations greater than 3 minutes, due to feedback from the users and an interest in seeing how well volunteers would perform on longer video segments. Additional video segments were generated with 5, 10 and 20 minute durations, and as the original videos did not divide evenly, some segments were of less duration. Table 1 provides a breakdown of how many segments were watched of each duration, as well as how many were flagged as valid, invalid or inconclusive. Observations were marked valid if they were part of the quorum of observations, *i.e.*, if 3 users specified the bird was on the nest, and 2 did not, the 3 on nest observations were valid and the 2 off nest observations were invalid. In general, it seems that video segments between three and five minutes provided the most consensus from users, and longer video segments reduced user consensus.

Of the 108,818 video segments marked by volunteers, 25,549 corresponded to videos that were marked by the projects experts. Table 2 compare the volunteer's results to the experts observations, which were obtained using the new interface. True positives (TP) were when a quorum of volunteers marked an event as occuring a video segment, and the times of the video segment overlapped with the time of a similar expert event; false positives (FP) were when the marked event did not overlap with the time of a similar expert event; true negatives (TN) were when the event was not marked and an expert did not mark the event during that time; and false negatives (FN) were when the event was not marked and an expert did mark an event

Event Type	Total	TP	TN	FP	FN	Accuracy (%)
Bird Leave/Return	12501	154	8504	287	3556	69
Bird Presence	21230	9407	1338	9270	1215	51
Bird Absence	9540	1092	4680	2173	1595	61
Predator Presence	414	4	393	11	6	96
Nest Defense	33	0	33	0	0	100
Chick Presence	708	12	418	252	26	61

Table 2: Volunteer event quorums compared to expert events. True positive (TP), true negative (TN), false positive (FP), false negative (FN), and accuracy ($\frac{TP+TN}{total}$) percentages are given.

during that time. Bird leave and bird return events were unified, as the expert interface had a single event for a bird being in the video but not on the nest which is what these would match to. There were not enough nest success events to provide meaningful results.

Using this interface the volunteers provided good results for obvious events such as predator presence and nest defense (at 96% and 100% accuracy), and decent results for birds leaving and returning (69%), results for bird presence and absence were poor (51% and 59%), due to the difficulty of determining the presence of a bird during the short video clips.

4.2 New Interface

Results for the new interface have been gathered over the subsequence period of 9 months, from April 2014 to January 2015. 150 users provided 25,427 observations for 8,338 full length videos, with the average video duration being 53 minutes (durations ranged from 1 second to 11 hours). In total, this was over 49,457.5 days of video watched by volunteers. Of these observations, 137,895 were marked valid (by being marked by a quorum of volunteers, given a 5 second buffer for start and end times), 15739 were marked invalid, and 132 were inconclusive (either no quorum, or no other matching events).

Of the 8,338 full length videos observed by volunteers, 1,824 had observations from both a volunteer and an expert. Table 3 displays how well user observations matched to expert observations for a 5 second buffer, with Table 4 shows the same data for a 10 second buffer, for all observations that had more than 10 volunteer entries with corresponding expert observations. A 5 second buffer means that two events would match if they were of the same type and their start and end times were within 5 seconds of each other, and so on.

The misses column shows how many observations of a particular type could not be matched to an expert observation with similar start and end times. The type mismatch column shows how many observations matched an expert observation with similar start and end times, but a different event type. The match column shows how many observations fully matched an expert observation. The improvement in user observations is significant. With even a 5 second buffer, users correctly marking *on nest* and *not in video* increased to 85% and 74%, *off nest*, which meant that the bird is in the video but not on the nest, was similar at 68%. With a 10 second buffer, these increase to 87%, 79% and 73%, respectively. These represent significant improvements from the old interface for *on nest* and *not in video*, without losing accuracy on *off nest*, which would correspond to *bird leave/bird return* from the old interface.

Given these results, the *camera interaction* events are the most problematic, with many completely mismarked, and *attack* and *physical inspection* events showing significant type mismatches. The *video error* and *camera issue* events have high type mismatches, and these results

Event	Misses	Type Mismatch	Matches
Parent Behavior - Not In Video	221 (0.23)	23 (0.02)	708 (0.74)
Chick Behavior - In Video	13 (0.93)	0 (0.00)	1 (0.07)
Territorial - Predator	8 (0.53)	1 (0.07)	6 (0.40)
Territorial - Non-Predator Animal	14 (0.93)	0 (0.00)	1 (0.07)
Camera Interaction - Attack	12 (0.57)	9 (0.43)	0 (0.00)
Camera Interaction - Physical Inspection	22 (0.55)	7 (0.18)	11 (0.28)
Camera Interaction - Observation	9 (0.64)	3 (0.21)	2 (0.14)
Error - Video Error	12 (0.09)	7 (0.05)	120 (0.86)
Error - Camera Issue	12 (0.09)	47 (0.34)	78 (0.57)
Parent Behavior - On Nest	484 (0.11)	152 (0.04)	3686 (0.85)
Parent Behavior - Off Nest	315 (0.31)	16 (0.02)	701 (0.68)

Table 3: With a 5 second buffer for matching, how many full misses, type mismatches and full matches were found for observations with more than 10 volunteer entries that had matching expert entries. Type mismatches were when a user had matching start and end times, but marked a different type of event. Percentages of total events of that type are shown in parenthesis.

Event	Misses	Type Mismatch	Matches
Parent Behavior - Not In Video	177 (0.19)	26 (0.03)	749 (0.79)
Chick Behavior - In Video	13 (0.93)	0 (0.00)	1 (0.07)
Territorial - Predator	8 (0.53)	1 (0.07)	6 (0.40)
Territorial - Non-Predator Animal	13 (0.87)	1 (0.07)	1 (0.07)
Camera Interaction - Attack	10 (0.48)	11 (0.52)	0 (0.00)
Camera Interaction - Physical Inspection	12 (0.30)	14 (0.35)	14 (0.35)
Camera Interaction - Observation	7 (0.50)	4 (0.29)	3 (0.21)
Error - Video Error	12 (0.09)	7 (0.05)	120 (0.86)
Error - Camera Issue	12 (0.09)	47 (0.34)	78 (0.57)
Parent Behavior - On Nest	409 (0.09)	168 (0.04)	3745 (0.87)
Parent Behavior - Off Nest	253 (0.25)	29 (0.03)	750 (0.73)

Table 4: With a 10 second buffer for matching, how many full misses, type mismatches and full matches were found for observations with more than 10 volunteer entries that had matching expert entries. Type mismatches were when a user had matching start and end times, but marked a different type of event. Percentages of total events of that type are shown in parenthesis.

show that the two events should probably be merged as they are similar enough to not matter. The issues with *territorial* events need to be addressed by providing more information to the volunteers and a more in depth examination on a per video basis of why they were mismarked.

There are a few hypothetical reasons for this. First, in a recent survey taken of Wildlife@Home users, only 38% considered themselves fluent in English. It is possible that while there are extensive instructions on how to properly mark events, there are not translations of these, making it challenging for some vounteers to understand some of the nuances between these event types, *e.g.*, the difference between a bird observing, physically inspecting, or attacking a camera. Second, these events happen infrequently compared to *on nest*, *off nest*, and *not in video* events. Either the limited number of samples is not portraying an accurate representation of how the users are classifying these events, or users haven't had enough experience with them being validated correctly or incorrectly to appropriately learn how to mark these events.

	Easy	Medium	Hard
Misses	2529 (0.15)	145 (0.14)	90 (0.20)
Type Mismatch	1056 (0.06)	57 (0.05)	24 (0.05)
Matches	13774 (0.79)	863 (0.81)	330 (0.74)

Table 5: How many misses, type mismatches and matches were made by users depending on how hard they marked the difficulty of determining the observations.

4.3 Reported Difficulty vs. Correctness

Table 5 shows how accurate the volunteers were depending on how difficult they marked the video. Interestingly, videos with medium difficulty had the highest accuracy at 81%. Videos marked as hard had the most misses percentage wise, which is to be expected. However, apart from easy and hard, there was not much difference in user accuracy depending on how hard they marked the video. Type mismatches did not seem to have any correlation with user reported difficulty, which can sense as type mismatches are because of users misunderstanding how to mark events.

5 Conclusions and Future Work

This paper describes significant improvements to the crowd sourcing interface of Wildlife@Home. The original interface provided a simple method for users to mark yes, no or unsure for various events within short clips of video (see Figure 2); while the new interface allows users to watch full length videos and enter any number of events with specific beginning and ending times, tags and comments (see Figure 3). This new interface provided a dramatic reduction in the amount of storage resources required to host the over 85,000 hours of avian nesting video gathered for the project, as the original interface required the archival video to be converted into short segments which needed to be in multiple formats for HTML5 video streaming.

Using the original interface, users had significant trouble determining the presence or absence of a bird in the short video segments, which contained varying weather conditions and cryptically colored (camouflagued) birds The original interface had an approximately 51% accuracy rate compared to expert observations, which was barely better than guessing. With the new interface, users ability to determine bird presence at the nest increased from 51% to 87%, bird absence from 61% to 74% and bird presence off the nest from 69% to 73%. While being able to get significantly better information on many events from the users, this interface also allowed for a direct comparison of user observations to expert observations and uncovered potential improvements to be made, especially in the cases of *camera interaction* events and *video/camera error* events. These can potentially be improved by further user education and the addition of translations as many of our volunteers are not native english speakers.

These results show that it is possible to get accurate results from the public for classifying challenging video for scientific purposes, with proper education and instruction. While this is signficiant on its own, and Wildlife@Home's users are providing valuable information about avian nesting behavior, this is not the final goal for the project. For future work, we will be codifying these observations that have also been validated by project scientists and developing a data set for computer vision researchers. The end goal is to use this information to develop computer vision algorithms which will be able to automate the arduous task of classifying events within these videos, or at the very least filter out video where nothing is happening. Lastly, Wildlife@Home is open source[1], and has been developed with the ability easily add additional

[1] https://github.com/travisdesell/wildlife_at_home

projects and data sets, which will prove valuable for other wildlife ecologists who require the analysis of large scale data sets.

6 Acknowledgements

We would like to thank all the dedicated Wildlife@Home volunteers who have spent so much time watching video and providing helpful feedback. This work has been partially supported by the National Science Foundation under Grant Number 1319700. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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