UC Berkeley School of Information Graduate Thesis

WHIRLD

ONLINE COLLABORATION FOR AERIAL IMAGERY

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For the Phantom- we barely got to know you

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INTRODUCTION

The University of California, Berkeley School of Information is unique in bringing together diverse people, diverse theory and diverse technology. Whirld is the result of this diversity. We have overlapping skillsets in user experience research, interface design, web development, database administration, machine learning, and product management. Together, we applied the tools and techniques we have learned from courses in information visualization, social theories of information, interface design, user research, machine learning, and information law and policy to this project. This work has resulted in a web platform accessible at whirld.net, a presentation to our peers and faculty delivered on March 14, 2015, a video highlighting the implications of our work, and this report.

Whirld reflects the I School's aim to tackle forward looking problems by blending social, economic and legal knowledge with technical expertise. Our focus on aerial imagery and Unmanned Aerial Vehicles (UAVs) highlights the complex and undetermined implications of these technologies and the benefits of an I School approach to tackling such technology challenges. Whirld supports the I School's aim of "expanding access to information and to improving its usability, reliability, and credibility," [1] and we are excited to present this report as part of our Graduate Thesis Project for the Master of Information Management & Systems Degree.

1. About. UC Berkeley School of Information. <http://www.ischool.berkeley.edu/about>

BACKGROUND

In the past twenty years we have lived through a revolution in aerial imagery. Historically, it was nearly impossible to view the Earth from above. We marvel at the Nazca lines because they demonstrate a people and culture abstracting from their viewpoint and imagining an aerial perspective they would never see themselves. Actually having an aerial view didn't become a practical possibility until the advancements of flight in the early 20th century, and it has only become more accessible with the development of satellite imagery in the late 20th century. Who doesn't remember looking up their home from above when they first got access to Google Satellite view?

The next twenty years will see an even more significant impact on society from aerial imagery with the rise of consumer access to it. On one hand, new technologies, such as unmanned aerial vehicles, or "drones," and new applications of old technologies, like balloons and kites, have the potential to democratize aerial imagery for citizen projects. Government agencies, the military, and major technology firms will no longer be the only ones able to access and use aerial imagery. On the other hand however, an increase in the use of drones, in particular, raises a number of questions around privacy, security and ethics. Right now, only the military and a handful of major technology companies are poised to influence the answers to these questions; they control the future of drone applications and the social norms and expectations for these technologies.

We approached the impending proliferation of aerial imagery, and the potential issues with which it will come, with the goal of promoting positive ways for individuals and communities to interact with, apply and develop the future of aerial imagery technologies. We hope to democratize the types of work accomplished with drones and aerial imagery and enable individuals to wrest control of these technologies.

CORE PROBLEM STATEMENT

Consumer grade drones have made it easier than ever to take aerial photographs and video, but systems for sharing, accessing and analyzing aerial imagery and video have not kept up with the ability of this technology to collect data. We are increasingly able to take pictures and videos in new ways and from new perspectives about our environment, but the mechanisms by which we are able to create value from this information are lacking. New solutions are required to help individuals organize, analyze and share this information and resolve three key aerial imagery challenges.

Technological Change: Currently, having read-only, out-of-date access to satellite imagery, by the grace of governments and large corporations, is the highest expectation for aerial imagery. While ancient technologies such as balloons and kites still hold value in some specific use cases for capturing aerial imagery, the rapid technological advances and decreasing prices of drone technologies in both the commercial and consumer sectors have the potential to put aerial imagery in the hands of citizens. There is great potential for technology to empower citizens to not only make use of this information but also influence the social norms and expectations for these technologies going forward.

Underutilized Communities: There are existing, rapidly growing communities of users of drones who are engaged with drone technologies but lack purposeful destinations to translate the data they collect into information that adds value. The images and video collected by these devices can serve as valuable information sources and powerful narrative tools. These users do not have a seat at the table in determining what the future of drone technologies will look like, and they lack an online space to collaborate with other social groups who can make use of the information they gather.

Communication & Informational Gap: Social norms and identities surrounding drone technology are in flux, and it is no wonder that there exists a communication and informational gap among drone users and creators and the general public who might benefit from them. For what can drones be used? They can give us aerial imagery, but how exactly might we make use of it? In California, for example, a state experiencing environmental change at many time scales, there is a need for the public to observe how changes in vegetation, snowpack and waterways, often driven by severe drought, significantly impact their state as a whole and their local communities. Trained experts in the field may be able to digest information about such changes when summarized in quantitative data or technical reports, but these forms of media often fail to inform or motivate the public. The organization and visualization of environmental change is crucial, but it is currently difficult to do so. How might the collection of aerial imagery by citizen drone users help the situation?

A forward thinking solution is required that approaches the increasing ability to collect aerial imagery and video with knowledge of what makes information valuable and how it can be used to create and tell compelling analyses and stories. At the same time, such an approach must understand that these technologies will potentially remain popular only within certain communities, taking decades to achieve common usage among most segments of the population. As soon as possible, it must not only link early adopters to other communities to whom aerial imagery might be valuable, but it must also serve as a breeding ground of sorts, for positive uses of drones and aerial imagery, by enabling the discovery and creation of a range of use cases for such technology and information.

SOLUTION

We developed Whirld, an application for collaborating on drone and aerial imagery projects. Whirld brings together drone hobbyists, citizen scientists, journalists, and community leaders, so they can make use of aerial imagery collected by drones. It facilitates peer production and connects individuals to projects they might not otherwise know about, while also serving as a repository for aerial imagery and videos that might otherwise remain invisible. Most importantly, it creates a positive vision of what drone and aerial imagery technologies can achieve in the future.

PROCESS

We worked in concurrent paths, researching drone and aerial imagery technologies, the user communities amongst drone enthusiasts and in fields like mapping, citizen science, and iteratively developing product designs and prototypes.

TECHNICAL AND DOMAIN RESEARCH

Our technical research pursued multiple paths in parallel. We researched drone hardware and software specifications, aerial imagery solutions, geographic information systems and web mapping tools, citizen science projects, and online collaboration platforms.

UAVs: While we were inspired by drone technologies, we did not immediately assume they would be the focus of our project. We were inspired by Public Lab, with whom we had an existing relationship, and their focus on using simpler hardware technologies like kites, balloons and poles, together with complex software. However, we recognized that while drone technologies were becoming increasingly cheap and accessible, their communities were not present on Public Lab.

When Public Lab grew out of a Grassroots Mapping[1] project following the Deepwater Horizon oil spill in 2010, commercial drones were still in their infancy. As of 2014, the global unmanned aerial systems (UAS) market sits north of $600 million, and is forecast to near $5 billion dollars worldwide by 2021.[2] It is estimated that 200,000 commercial drones were sold in the US in 2014, with a doubling of sales projected for 2015.[1] Major technology companies like Facebook, Google and Amazon have proposed commercial drone systems, and hobbyist communities like DIYDrones have launched successful drone companies like 3D Robotics right here in Berkeley. The FAA released proposed regulations for the use of drones during this project, and the feedback period for these regulations continues.[2] While the future of drones under the law is unclear, the space is currently clear for drone owners not focused on making money from their drones. Current regulations require licensing for commercial use, although the FAA has backed down from pursuing cases of tangential commercial factors, such as drone pilots who post to a commercial site like YouTube.[3] As such, there is a currently no outlet for innovative applications of drones to meet demand and solve real problems outside of the commercial enterprises that are being slowed by FAA regulations.

While technologies like balloons and kites could still serve as valuable tools in certain use cases, the decreasing cost of drones and their increasing ease of use would open up far more opportunities for innovative applications of aerial imagery than currently exist. We began testing with a Hubsan X4 Quadcopter, a Parrot AR Drone, and then a DJI Phantom Vision 2. With each device, we learned more about both the technical capabilities of drones and the user experience with such a tool. For instance, while the DJI Phantom is one of the most common drones on the market, particularly for filming, it's onboard camera had a significant fisheye effect for many aerial images. Contextually, we also learned about the user experience as a drone pilot. Sometimes it felt natural to fly the drone in a park, whereas other times it drew a crowd of intrigued watchers. Having that context for what it feels like to be a

2. Grassroots Mapping Kickstarter Origin Story. https://www.kickstarter.com/blog/case-study-grassroots-mapping
3. Commercial Drones: Highways in the Sky,Commercial Unmanned Aerial Systems(UAS),Market Shares, Strategies, and Forecasts, Worldwide, 2015-2021. Radiant Insights. http://www.radiantinsights.com/research/commercial-drones-highways-in-the-sky-commercial-unmanned-aerial-systems-uas-market
4. Booth, Barbara.December 22, 2014. "Is it time to buy your kid a drone for Christmas?" CNBC. <http://www.cnbc.com/id/102280825>
5. Operation and Certification of Small Unmanned Aircraft Systems. FAA. https://www.faa.gov/regulations_policies/rulemaking/recently_published/media/2120-AJ60_NPRM_2-15-2015_joint_signature.pdf
6. Koebler, Jason. March 12, 2015. "The FAA Says You Can't Post Drone Videos on YouTube." http://motherboard.vice.com/read/the-faa-says-you-cant-post-drone-videos-on-youtube

drone pilot and understanding how others see the pilot was critical for us in imagining what environments and situations (both currently and in the future) could be captured by drone.

Aerial Imagery: Aerial imagery tools come in a variety of shapes and sizes. Google Maps satellite view is the most commonly used imagery tool. It has almost no analytical features, but meets a need for users trying to understand what an area looks like beyond the traditional street layout. At the other end of the spectrum are tools like Pix4D, a mapping and modeling tool that converts aerial images into tiled mosaics and three dimensional models.[1] The divergent uses and technical requirements of these tools emphasizes the recency of aerial imagery tools.

Historically, aerial imagery solutions have been primarily used by researchers, scientists and engineers for remote sensing. Google's satellite view aggregates from many sources that were unavailable to most businesses and consumers due to legal and technical requirements until the past twenty years. These data sources range from satellites to scheduled flyovers by imaging planes. Google's ability to process these sources into a consumer friendly form has made them the dominant players in imagery basemaps. To bypass Google's dominance of accessible imagery, we initially considered using an API that NASA makes available from a set of satellites but were deterred when we realized that satellite imagery and remote sensing are still inaccessible to most people. The file sizes, data structures, and analysis required to understand the imagery require more expertise than most people, who interact with aerial imagery as a toggle in Google Maps, have. This expertise more closely resembles what is required to work with powerful imagery analysis tools like Pix4D. Many of these tools have been developed in the past few

7. Pix4D Homepage- Accuracy and Efficiency. <https://pix4d.com/>

Testing different technologies, from popular drones like the DJI Phantom to Public Lab's balloon kit, allowed us to better understand the challenges and capabilities of aerial imagery capture and drone operations. Sadly, the hands-on lesson by Professor Cheshire was not enough to prevent the tragic demise of the Phantom.

years in parallel with the increasing affordability and accessibility of aerial images from drones. However, they remain proprietary and often focused on specific industries and use cases.

We felt that an open source solution was critical to facilitating collaboration and democratize access to imagery and drone projects. The DIY, open source environmental community Public Lab's Mapknitter tool was a clear starting point for aerial image analysis.[1] Mapknitter allows stitching of photos together on a basemap—either a street layout from OpenStreetMap or Google's satellite imagery. It allows multiple photo taken from any source to be stitched together into one consolidated view of the landscape. It allows non-technical users to stitch together aerial images that might contain information that Google's images do not.

To understand how else, besides Mapknitter, we could make use of aerial imagery, we began with competitive research. As a part of the I School's INFO 214: Needs and Usability class, we methodically analyzed ten tools, both proprietary and open source, that involve aerial imagery to some degree. Hoping to gain a comprehensive overview of the tools currently in use we asked and answered the following questions about them:

- Who are their target users?
- What features do they have?
- In the context of similar products, what considered features are they missing?
- How does their design perform?

The ten products were divided into three main categories—Direct Competition, Generic Mapping tools, and Narrative Mapping. The first category, Direct Competition, looked specifically at products that use drone aerial imagery to collaborate with maps. The second, Generic Mapping, was comprised of products more similar to traditional GIS tools; that is, mapping tools with little to no collaboration and only satellite imagery. Finally, the third category of existing products, Narrative Mapping, was described as "mapping with a purpose" and was characterized by mapping with the addition of narrative text and multimedia assets.

After filling out a spreadsheet of what each product has, does not have, who its target users are, and how its design performs, and then considering all of that in the context of both what type of product it is meant to be, as well as informational interviews we had also been conducting, the team was able to diagram some user flows and identify gaps missing in the current landscape.

Specifically, the following was clear:

- There are tools that take advantage of aerial imagery for commercial purposes. MapsMadeEasy and PIX4D (Direct Competition), for example, allow users to upload photos and build maps and 3D models. These proprietary systems, however, are designed for use by a single customer/client. As such, the opportunities for innovative uses of drones/aerial imagery and discovery of new approaches to these technologies are limited.
- There are traditional mapping tools whose imagery is proprietary, often outdated, and inaccessible to the average person.
- There are narrative mapping tools that provide rich experiences for highly specialized situations, but they offer few technical capabilities and do not take advantage of the imagery drones can provide.
- While Public Lab encourages collaboration from many stakeholders on projects, and the other companies do not, direct collaboration and peer production on a project within the Mapknitter platform is exceedingly difficult.
- None of the tools make it easy to establish an open ended project that might grow and change.

Competitive research not only revealed that there is no tool for the hobbyist drone user to make use of his or her imagery, but there is also no good place for people who want to use such imagery to browse, use, or collaborate with it. Such findings not only provided a framework by which the team was able to decide on, design, and develop features going forward, but they also confirmed the suspicion that combining a number of these aerial imagery features would be a powerful proposition. Going forward then, we aimed to bring together:

- the pattern of discovery via aerial imagery that tools like Google Earth offer
- the mapmaking and project creation ability of PIX4D or Mapknitter
- a new ability to effectively collaborate on aerial imagery projects within the tool itself
- a new ability to continue open ended aerial imagery projects, rather than upload information and define a single output product, to take advantage how aerial imagery can track change over time.

Mapping: There has been an incredible proliferation of mapping tools in the past ten years, many of which have facilitated some of our goals—peer production, online collaboration, and open ended, crowd sourced projects. We tested tools from CartoDB, Mapbox, and other companies which have taken mapping from a GIS-centric perspective to allow more flexible, collaborative web maps. Few of these products emphasize aerial imagery, however, with most using Google imagery as an option for a basemap and emphasizing the user's ability to add point, line or polygon data on top of these base maps.

Whirld sits parallel to these products, offering users the opportunity to collect, upload and analyze spatially referenced images and video, rather than data sources like tweets or Census data. We felt that integrating outside data sources beyond images and video was out of scope, and would be an attempt to make a mapping tool that was everything for everyone. However, a project developed on Whirld could be integrated effectively with geospatial data beyond just images and videos in a tool like ArcGIS, CartoDB, or Mapbox. And we did take a few features from web mapping tools that users would find intuitive and could serve as reference information for the images and videos. While maps can be made from downward facing images taken by a drone, other images and videos can be tagged to locations as points or lines, providing a layer of additional information on top of a map.

Citizen Science: Citizen science allows non-specialists to contribute to formal scientific research, and many of the civilian applications of drone technologies relate to citizen or crowd-sourced environmental science research.[1] As such, we initially drifted towards improving specific uses for drone technologies that could be applied to citizen science projects.

As of November 2014, there were a variety of individual citizen science projects being developed for drones and aerial imagery projects. iNaturalist, in fact, has used drones in its "bioblitzes" here in the Bay Area.[2] However, few methods existed to connect and start new projects supported by both the drone and citizen science mapping communities, which are usually disjointed. The small number of citizen science groups who do use drones are often locally based, organized around a geographically close set of people with shared interests and passions. We discovered that the greatest impact wouldn't come from developing a new citizen science application of drones itself; instead, Whirld could help people identify and share their own uses for drones, many of which might incorporate citizen science. With this in mind, we did not develop Whirld to support only citizen science, but we envision citizen science as one set of collaborative projects that could be developed and grow out of Whirld.

While we decided not to design exclusively for citizen science, we were able

9. What is Citizen Science? Scientific American. <http://www.scientificamerican.com/citizen-science/>
10. Thaler, Andrew David. "Drones, Robotic Rovers and Citizen Scientists Join Forces to Sample a Lake's Biodiversity." *Scientific American.* <http://www.scientificamerican.com/article/drones-robotic-rovers-and-citizen-scientists-join-forces-to-sample-a-lakee28099s-biodiversity/>

to identify a number of key takeaways from citizen science to apply to our solution.

We spoke with academics and scientists about their work with drones for research, including staff at the United States Fish & Wildlife Service and drone researchers at Humboldt State University. We investigated citizen science projects like MicroMappers, which uses analysis of aerial imagery of natural disasters to facilitate humanitarian response. We thought deeply about iNaturalist, which grew from an I School project into an incredibly successful citizen science program. iNaturalist, like other successful citizen science projects, had a clear goal, and utilized crowdsourcing to achieve it.[1] Citizen science has a rich history in recent years, seeing volunteers classify over 900,000 photographs of galaxies in the Galaxy Zoo Project and over 100 million sightings of birds worldwide. We observed that one of the most important factors behind the success of these major citizen science projects was their ability to engage users and allow them to make a significant contribution to a meaningful, ongoing scientific project.

We determined from citizen science projects that “variety and autonomy are important in ensuring greater job satisfaction, ”[2] and our attention was drawn to the idea that a good system is built with “room for the uninvited/underdesigned and room for failure”[3]. We see in Public Lab, for instance, many unfinished projects that might have value. It has created a community and a set of tools where, while some projects may be hugely successful, failure of an individual contribution is very accepted. At the same time, many citizen science projects have a many-to-one relationship. That is, contributions are submitted towards a repository or end goal. NASA’s Clickworkers, for instance, contribute their time and energy towards specific goals of NASA. While this works for projects with

11. Nov, Oded, Ofer Arazy, and David Anderson. “Crowdsourcing for science: understanding and enhancing SciSourcing contribution.” ACM CSCW 2010 Workshop on the Changing Dynamics of Scientific Collaborations. 2010.
12. Springs, Morley, Bamford and Houghton. The Impact of Task Workflow Design on VGI Citizen Science Platforms. GIS Research UK Conference, Leeds University, 2015. <http://leeds.gisruk.org/abstracts/GISRUK2015_submission_39.pdf>
13. Hemment, Drew and Edmonds, Ernest. Environment 2.0. Leonardo, February 2011, Vol. 44, No. 1, Pages 62-63. <http://www.mitpressjournals.org/doi/pdf/10.1162/LEON_a_00096>

specific targets, it is ineffective for building communities of contributors who can creatively identify new projects and targets that the tools make available.

What was missing in the drone and imagery space was a user community that would collaborate to produce engaging and quality projects. Peer production could “decentralize the conception and execution of problems and solutions [and] harness diverse motivations” and free our users from specific task requirements.[1] Accessible, effective online collaboration and peer production was missing from many of the technologies, projects and platforms we investigated across UAVs, aerial imagery, mapping and citizen science.

These lessons from citizen science emphasized the importance of building a strong community, rather than ensuring specific user generated content. During this process we perceived the need for a digital community that would enable efficient retrieval of data, connect people of different skillsets, and allow collaboration that transcends colocation, and we incorporated these features into Whirld.[2]

Online Collaboration and Peer Production: While we had originally been interested in bringing together both drone enthusiasts and individuals who had an unmet need for aerial imagery and video, our research across UAVS, aerial imagery, mapping and citizen science emphasized how critical it would be to have an effective method of online collaboration. Our research across academic studies and industry examples of both digital collaboration and peer production emphasized a few key takeaways for our platform.

As noted, there are a diverse set of tools for the citizen science, mapping and drone communities. However, few facilitated collaboration by a large

14. Y. Benkler, Peer Production and Cooperation, forthcoming in J. M. Bauer & M. Latzer (eds.), Handbook on the Economics of the Internet, Cheltenham and Northampton, Edward Elgar. <http://www.benkler.org/Peer%20production%20and%20cooperation%2009.pdf>
15. Wiggins, Andrea. “Crowdsourcing science: organizing virtual participation in knowledge production.” Proceedings of the 16th ACM international conference on Supporting group work. ACM, 2010.

user group accessible to individuals from outside of these networks. We realized that an effective peer production platform would cover many more types of contributions than what these existing products offered. “Not all peers have to be identical: peers have different motivations, different skills, and therefore contribute in different ways.”[1] Citizen science is inherently an interdisciplinary movement, drawing together amateurs and experts, and a diverse set of skills between both.[2] An effective citizen science community provides a way for users of different backgrounds to meet and collaborate, and make contributions based on their individual strengths. Of the three types of citizen science communities defined by Bonney et al., we sought to support the co-created community, in which both scientists and volunteers shape the goals of a project and both groups may collect data.[3]

Members of a distributed citizen science community may perform different roles, analogous to species in an ecological niche. Citizen science members contribute data while professional scientists, if present, may structure some of the community’s goals to align with major concerns in the field. Among the citizen scientists, there are a number of roles that participants may adopt. Previous studies have identified the phenomenon of “power users,” a group of users who produce the bulk of the data housed on a citizen science platform.[4] On the opposite side of the spectrum are lurkers, a type of member present in the majority of digital communities, who consume information rather than producing it, but may play a valuable role in requesting information, giving feedback, and propagating it across social networks by sharing.[5]

16. Chuang, John. University of California, Berkeley, INFO 234: Information Economics. Lecture: April 29, 2015.
17. Jirotka, Marina, Charlotte P. Lee, and Gary M. Olson. “Supporting scientific collaboration: Methods, tools and concepts.” Computer Supported Cooperative Work (CSCW) 22.4-6 (2013): 667-715.
18. Bonney, Rick, et al. “Citizen science: a developing tool for expanding science knowledge and scientific literacy.” BioScience 59.11 (2009): 977-984.
19. Bo Gura, Trisha. “Citizen science: Amateur experts.” Nature 496.7444 (2013): 259-261.
20. Tedjamulia, Steven JJ, et al. “Motivating content contributions to online communities: Toward a more comprehensive theory.” System Sciences, 2005. HICSS’05. Proceedings of the 38th Annual Hawaii International Conference on. IEEE, 2005.

It became clear that Whirld should not be structured as a community of which only those who actively contribute could be a part; “free-riding” as a reader could in fact be a positive if it connected with contributions from mechanisms like page views or upvoting. “Research has shown that social and psychological influences such as the approval of others and gaining reputation can promote participation in collective efforts.”[1] From there, Whirld could facilitate an easy transition from reader to active participant.

In creating Whirld, we also sought to examine the effects of some of the major factors in motivating collaborative citizen science project discussed by Rotman et al. The study conducted by Rothman et al. in 2012 examined egoism: the desire to benefit one’s self; collectivism: the desire to aid the community; altruism: the desire to help others; and principlism: the desire to uphold personal morals, in citizen science collaboration, and found that explicit acknowledgement of volunteer motivation was more significant over time than their specific reason for participating. Taking this temporal model in mind, we also focused on the way in which principlism, collectivism, and altruism in Citizen Science align well with the open source software movement.[2]

As such, our solution should make different levels of contribution easy, and encourage both extensive involvement (such as a drone pilot who regularly uploads aerial photos, builds maps and submits videos) and minimal involvement (such as a person who noticed a project in their neighborhood and adds some cell phone photos or text description of their perspective).

USER RESEARCH

Our solution seeks to address a gap in information available and information being effectively used that is growing rapidly due to advancing technology. To determine the mechanisms by which we would do so, we required forward thinking user research that focused on possible users who might benefit from our open solution. While we don't see Whirld as a product for everyone and everything, we envision it as a platform that is flexible for a greater diversity of uses than many of the commercial and nonprofit solutions in this space today.

Our user research focused on members of the drone and robotics community, members of the mapping community, and a diverse collection of individuals who expressed a need or interest in aerial imagery and video. Our methods ranged from observation and informal conversations, to formal interviews to object-based participatory activities to, as we developed prototypes, user testing.

Observation

As part of the I School's INFO 214: Needs and Usability class, we conducted observations, paired with follow up conversations, of Public Lab contributors and drone users that we found on Meetup.com, such as the Game of Drones Unmanned Aerial Sports League.

Within the mapping community, we observed and talked to a variety of individuals who build their own aerial maps. For instance, we spoke with Public Lab community members Pat Coyle and Chris Fastie. Pat is a generalist, and has used drones, kites and balloons to make maps. He has used mapmaking to support nonprofit efforts with communities in Belize and support Engineers Without Borders. At the same time, he enjoyed just tinkering with the tools and trying new things out, even without a specific purpose. Chris built some maps for specific environmental projects and developed his own line of 3D printable aerial camera rigs.

23. Burham, Ragi. Telephone Interview. March 23rd, 2015.
24. Morris, Robert. April 14th, 2015. Flying into the Future- Drone Technology for Commercial Use. University of California, Berkeley.

Both are major proponents of open source communities and gave us a better sense of the kinds of technologists, engineers and citizen scientists interested in aerial imagery and mapping. However, there is basically "no overlap between drone community and mapping community."1 Many of the companies entering the drone mapping space come from the hardware space and focus on differentiating with their drones or from image processing backgrounds and emphasis the capabilities of image stitching and analysis.2

In general, by observing how drone users interact with the tools themselves, we began to characterize the drone user and develop an understanding of the drone community. Such observations, paired with follow up conversations familiarized us with the general personality of the drone community:

- Drone owners use drones for the hardware, more than for the software or the implications of drone technologies.
- They can be described as hobbyists, makers, and DIY'ers. They like tinkering with the drones the way someone else might work on their car.
- They were incredibly open and enthusiastic to share this hobby with others, whether this meant meeting up to fly with someone who didn't have a drone or trying new locations to fly their drone.

Drone enthusiasts loved the toy aspects of drones, such as their ability to fight, but were also enthusiastic about finding real world applications for their hobby.

Observations and follow up conversations also revealed some of the habits and attitudes drone users have regarding aerial imagery and collaborating with it:

- They are generally interested in aerial photography but rarely do more than share a few photos with families and friends or upload a video to YouTube.
- They love to fly their drones and would jump at the chance to take photos or videos for a friend or for submission to an interesting project
- They are concerned about the level of work and commitment and work it takes to sort through their photos and identify the most relevant.
- Finally, drone pilots were concerned about the FAA, and participation in projects is contingent on avoiding any licensing or government processes.

Conversations, Interviews and Focus Groups

While we conducted observations, we felt it was also important to connect with user groups not as technologically savvy or tied in with drones, aerial imagery or mapping to discover how they might find value in aerial imagery.

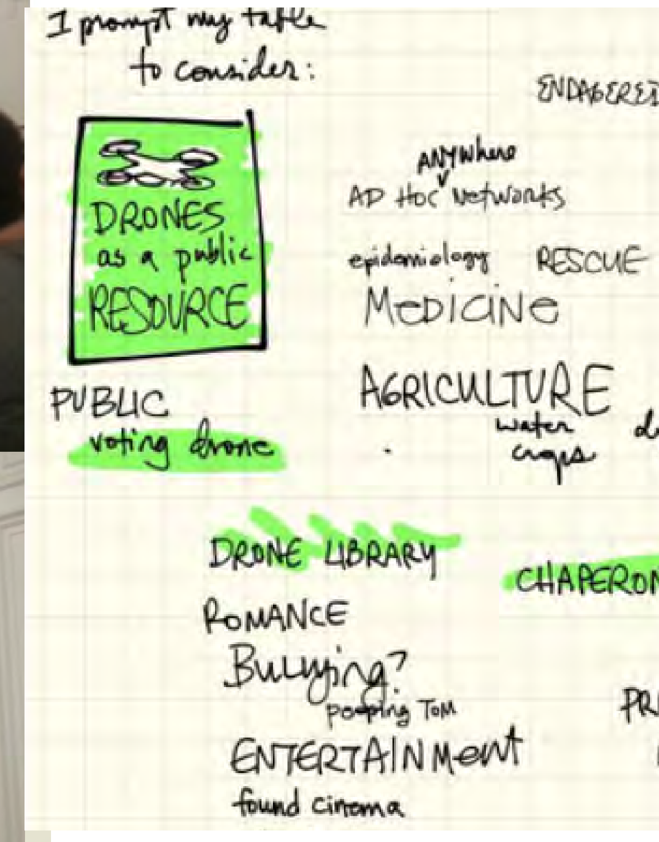
A formative experience in this piece of the process occurred in a UC Berkeley Journalism School class about Geojournalism, a form of journalism that "combines visualized data with geo-tagged stories to lend narrative to the data, and evidence to the narrative."[1] From observing and conversing with class participants, the notion that Whirld should enable collaboration across time and space was confirmed as participants repeatedly expressed the importance of creating "a common ground, common platform, common data from a network." Additionally, we learned that, to such potential users of aerial imagery, data is only as valuable as the narrative you can build from it.

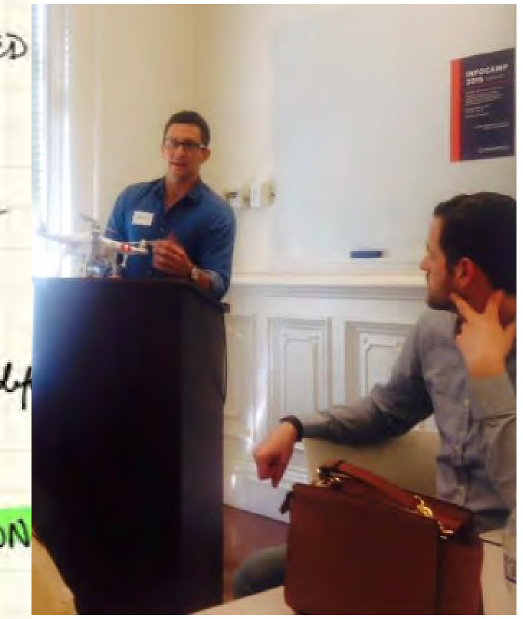
25. Fahn, James. Internews. Skype Interview: February 12, 2015.

We also explored how people outside of the drone or mapping communities think about these technologies, and we hosted two sessions at the I School's InfoCamp conference. The first brought people together to discuss the implications of drone technologies for society, and asked participants to propose socially positive applications of drones. The second focused on specific challenges of collaborating on drone and imagery projects, with participants brainstorming how online tools could be used for peer production to achieve more specific outcomes.

Engaging in audiences outside of the drone, citizen science, or mapping communities provided valuable context. For instance, participants in the social norms of drones discussion came in with very little understanding of drone technologies, what they were currently being used for and what they might be used for in the future. They provided a stark contrast with the drone hobbyists and industry members we met with, who not only imagined but were actively engaged in building a future where drones were ubiquitous. While InfoCamp participants struggled to move beyond the paradigms of military drones or the "toy quadcopter" style, drone experts were already picturing automated flight applied to other technologies. Davide Venturelli, founder of drone startup Archon told us "Tomorrow we will assume that anything, not just a 'drone' can fly. Drones will just be wings and software that you attach to anything or any sensor."[1] This contrast emphasizes the need for a place where people could propose, create and discover positive applications of drones. Government and commercial drone research and uses are expanding rapidly, but most of the public has little knowledge or ability to participate in this work.

26. Venturelli, Davide. April 14th, 2015. Flying into the Future- Drone Technology for Commercial Use. University of California, Berkeley.





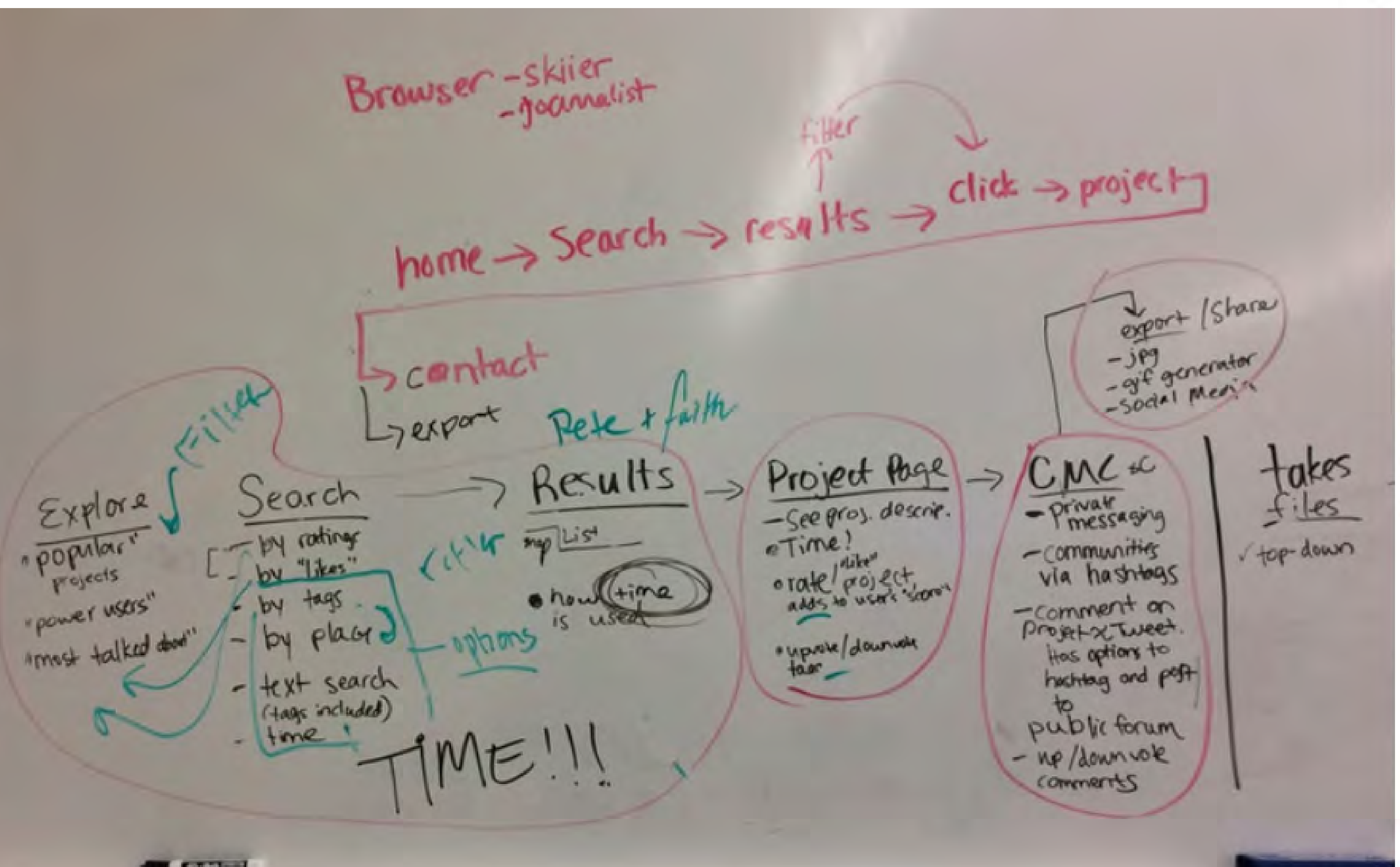
InfoCamp sessions on aerial imagery and social norms for drones connected us to a diverse set of individuals outside of the specific user groups we had been targeting, and helped us understand a wider array of perspectives on these technologies

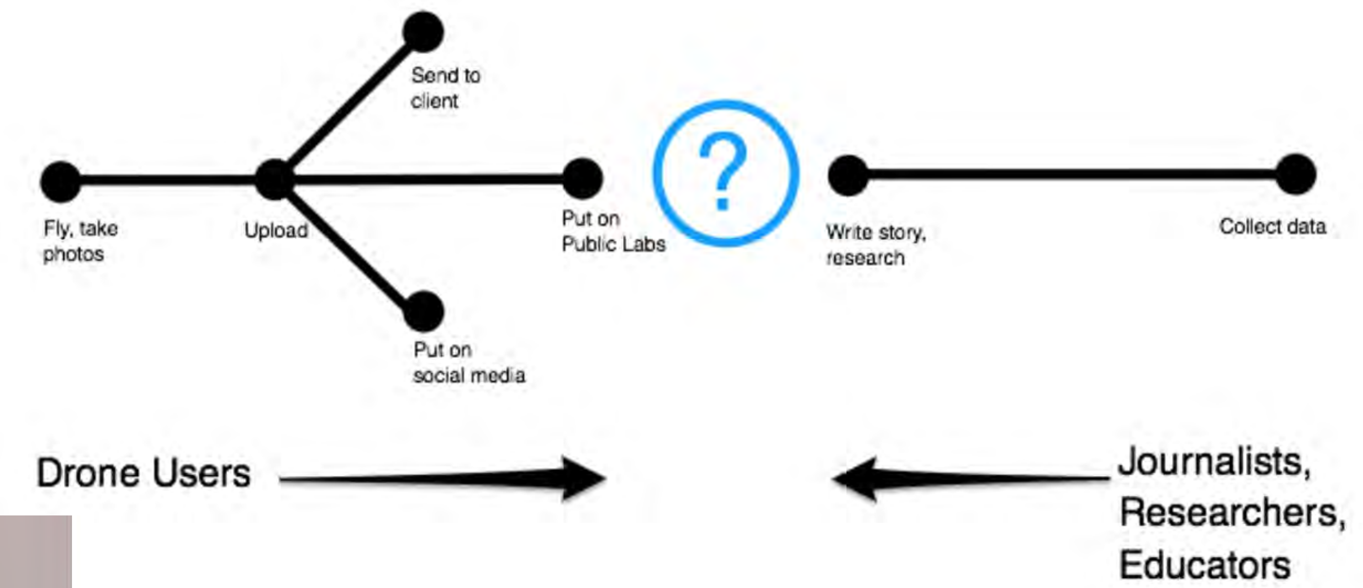
In our second InfoCamp session, we gave a short presentation on drone capabilities and various examples of aerial imagery before asking session members to brainstorm ideas on how drones could be used for a project countering drought in their hometown. Participants also gave their opinion on how to organize collaboration around drones. We gave each group sheets of paper to sketch possible interfaces. Suggestions about gamification came up, as did using drone part giveaways to motivate drone hobbyists to work towards citizen science. Although use cases of aerial imagery were shown before the presentation, it seemed difficult for participants to connect and engage with possible use cases, without a concrete dataset. As in our previous session, we observed that most knew a few isolated facts about drones from the news, but limited knowledge of the main technological capabilities and limitations.

User Flow Diagrams and Personas

Initial observations, interviews, and focus groups, alongside concurrent competitive and academic research, were summarized in several group meetings in the form of user flows, personas, and feature specifications. These preliminary deliverables provided the team with a strong framework as we went forward with design and development of Whirld.

An early analysis of different user groups helped us understand the gaps in current tools and activities. We found that we could make the biggest impact by bringing together drone users with people interested in telling stories with aerial imagery.





An early analysis of different user groups helped us understand the gaps in current tools and activities. We found that we could make the biggest impact by bringing together drone users with people interested in telling stories with aerial imagery.

Rachel represents one of the users on the "storytelling" side of the user coin.

Research

Persona 1

Rachel

AGE	Hobby	Familiarity with Technology
27 - 35	Running, hiking, traveling, photography, environmental activism	Medium

Rachel is an environmental journalist. This is her second career. She studied biology and worked in a lab for a few years after college. Upon returning to graduate school for journalism, she focused on reporting environmental issues in the developing world. Today, she works for an environmental newspaper that allows her to travel.

When Rachel is abroad, she works in interdisciplinary teams of scientists, programmers, community organizers, and makers that seek to combine environmental data with journalistic writing. This activity involves deploying sensors and other data-collecting equipment, educating locals on how to use them, analyzing the data, and reporting on it with data-backed narrative. Her work regularly appears on projects like Third Pole.

When Rachel is at home in the US, she organizes and participates in events for citizens to document their environments.

Jeff represents a drone user.

Research

Persona 2

Jeff

AGE	Hobby	Familiarity with Technology
32 - 58	Photography, flying RC's, hiking	High

Jeff got into drone flying as a natural progression from a lifelong hobby of RC flying. His day job is an engineer in Silicon Valley, but when he is not at work, he spends every spare moment flying his aerial vehicles. His preferred way to fly is FPV (first-person view), and the time he spends is definitely characterized as flying for the sake of flying. With the drones, he has begun to take photography and videography, but he views these things as simply a by-product of doing what he loves. That is, photography is not the end goal for him.

Even so, he has recently gotten attention for his photography and videography and landed clients in the agricultural sector. He assists his clients in setting up and flying "camera rigs." He offers no interpretation of the imagery he takes but simply hands over the images to the farmers.

His attitude towards doing "extra" things with his imagery is, if it is inline with the joy that flying gives him, or somehow enhances the efficiency or effect with which he can fly, he will do it. Otherwise, it is not worth his time.

Competitive Usability Tests

After gaining a high-level view of our competitors and characterizing our primary users, we needed to understand one or two products more thoroughly. For INFO 214: Needs and Usability, we conducted two usability tests on Google Earth Pro—an example of a proprietary mapping software that allows users to explore a broad range of spatial data—because it was most representative of the usability challenges we would like to address. In short, we watched two users explore their hometowns and answer various questions we asked them about what and how they perceived what they saw, as well as what information they were deriving from their activity.

This experience was incredibly informative for us; watching and listening to people browse and answer questions with multimedia on a map was fundamental in our understanding of what a usable feature like this is and is not and how we can improve upon it. In particular, we learned:

- ↘ Providing context is the most important consideration. When users are changing place on screen so much, they need anchors to where they are and where they came from.
- ↘ Thumbnails and pop ups on a map are not effective in conveying a sense of place. Other ways need to be generated.

Originally, we intended to extend this activity and conduct a formal competitive usability test with Google Earth Pro by going back and determining a battery of measurable usability goals that an ideal software application would achieve and then, compare how well our app achieves those to how well google earth achieves those goals. Unfortunately however, the timeline of our app was not such that it could be built in time to do this. (Appendix B)

Object-Based Activities:

After conducting competitive research and observing usability tests with Google Earth, we understood where and roughly how our project should be. Not only did we know that we should create an experience that creates value from aerial imagery and other media, but we also knew, in particular, that simply sticking thumbnail images or tooltip/popups on maps was not enough for users to either create or gather a holistic sense of place. We were left then, to discover what our project, and specifically, our map-based multimedia experience, should include. But when asking ourselves, "Exactly by what mechanisms could we provide context and convey a sense of place on or alongside a map?" we drew a blank, and we knew our users would as well. That is, simply asking users what we should do would not be sufficient; they needed objects to, as Goodman, et al. say in Observing User Experience, "use as props to think with and through."[27]

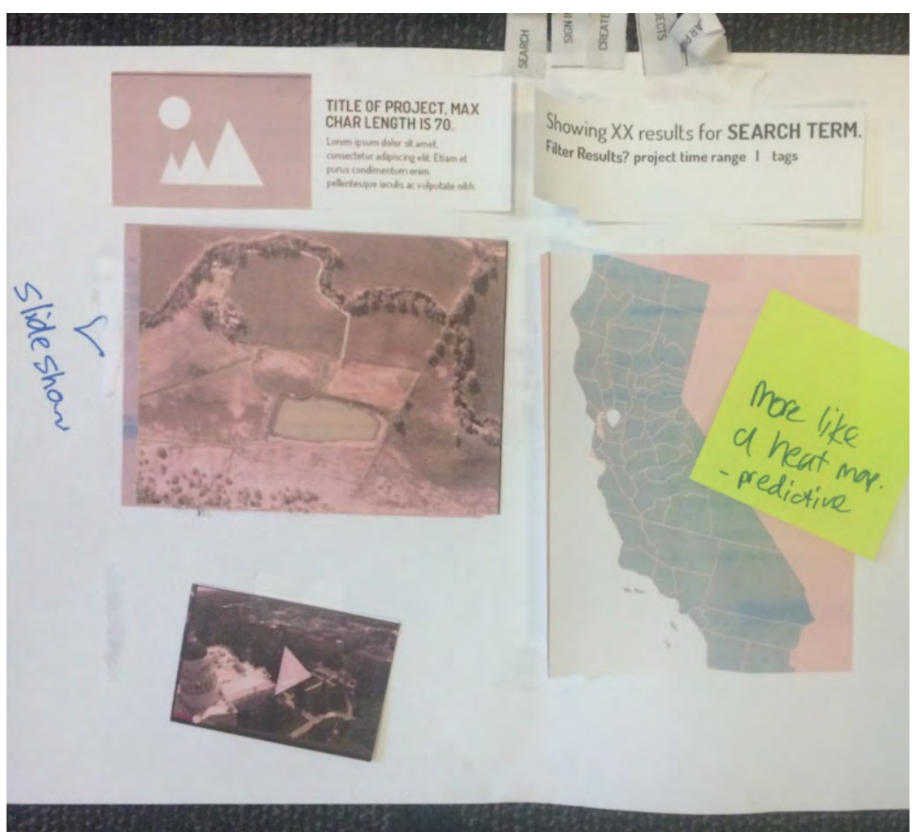
We chose an object-based activity to help our users express their own sense of place and us discover new designs for location-based multimedia. In particular, we planned a participatory paper prototyping activity in which participants chose one of two scenarios, were given a range of different paper representations of media components, and then asked to arrange them according to how they interpreted the scenarios.

After participants designed their notion of the interface, we followed up with short interviews about their layout choices and any obstacles or omissions they discovered along the way, making notes on the paper prototype as we conversed.

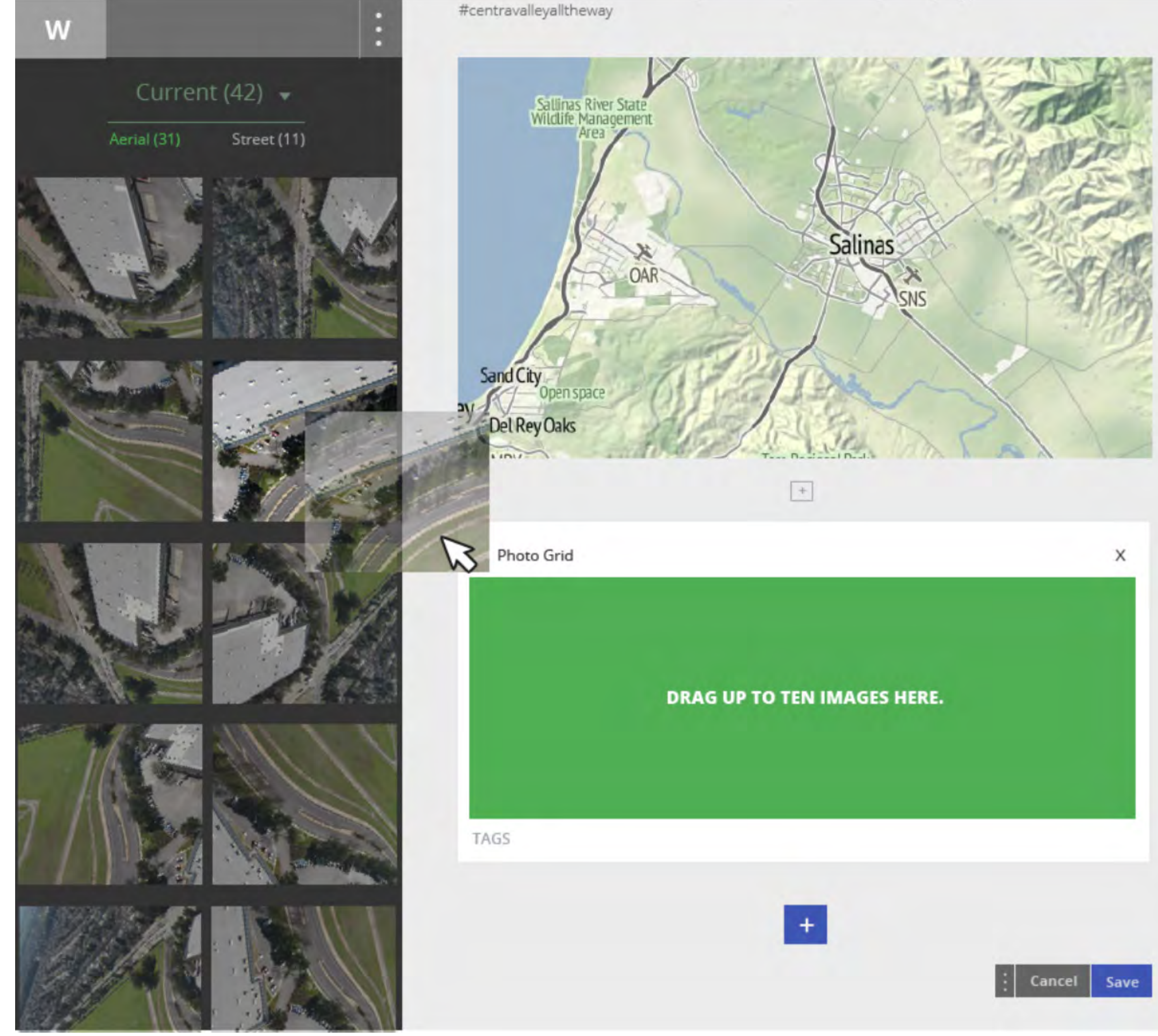
27. Goodman, Elizabeth, Kuniavsy, Mike and Moed, Andrea. Observing User Experience. Morgan Kaufmen, Burlington, MA.

Fortunately, the necessary timing for this activity coincided with the I School's New Admit's Day, at which current students were asked to exhibit projects. Recruiting was simple; Whirld set up a table at this exhibition for this research activity, and for two hours, current and prospective students and a few community members approached us to participate in our activity. In the end, a total of eleven paper interfaces were generated.

The paper prototypes gave us unexpected results. We expected to count what components users chose, extrapolate patterns from their choices, and, in the end, offer the user a particular layout or design. What we found however, was that the design solutions generated were as varied as the eleven participants and the mental models with which they were coming at our scenarios, and while we could gather what components they deemed useful, we could not comfortably, reliably



Example of finished user-generated paper prototype.



Sketch of project creation page; the participatory design exercise led us to design for modular content creation.

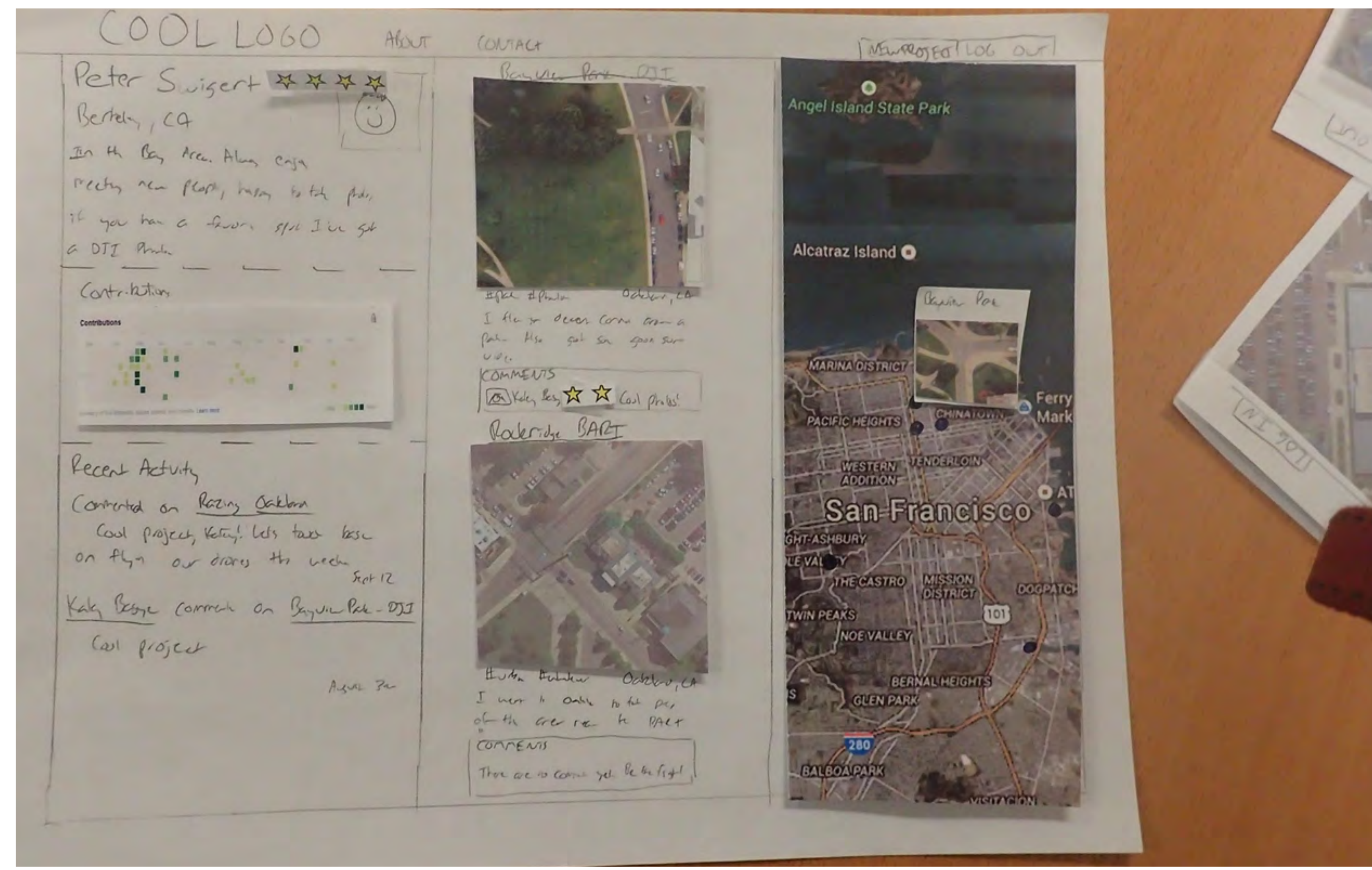
make recommendations in the form of a tidy, arrangement of interface components. The result of the paper prototyping then, was a design recommendation to enable modular creation of content by offering users a pre-defined set of components which they can arrange in any order they deemed fit. This way, each user can interpret and convey their own sense of their own place and, through concurrently developed aspects of the project, receive feedback on and assistance in doing so.

PROTOTYPING

Due to the limited time frame of this project, we prototyped in parallel to our technical, domain and user research. Beyond serving as a launching point for development of the actual platform and iterating on features, prototyping served as a valuable tool for aligning our team. A challenge of this project is that it proposes a forward thinking solution; the problem we address is not a specific pain point for a set of users that we could hone in on. As such, prototypes were valuable tools for putting our works into action, and confirm that everyone on the team could coalesce on a vision.

We started with paper prototypes. These designs show one initial proposal for what a user's profile page and home page might look like. Even this early in the process, however, the designs incorporate features and paradigms from across our technical, domain and user research. For instance, the profile page adopts Github's approach to tracking user submissions, as we aimed to encourage users to engage continuously with the product. We focused on keeping the images as clean as possible and moderating the amount of points, lines, data and tooltips that could be added onto an image, a valuable lesson that we took from our user testing with Google Earth. In particular, despite the seemingly obvious opportunity of automatically placing geotagged photos on a map or marking them with an icon, we did not allow users to place photos on a map unless they were aerial photos to build a map. Most users of our Google Earth tests found them to be ubiquitous and overwhelming, it was clear that users who were interested in a place could conceptualize where a landscape photo might have been taken from even if it was not tagged to a location on a map.

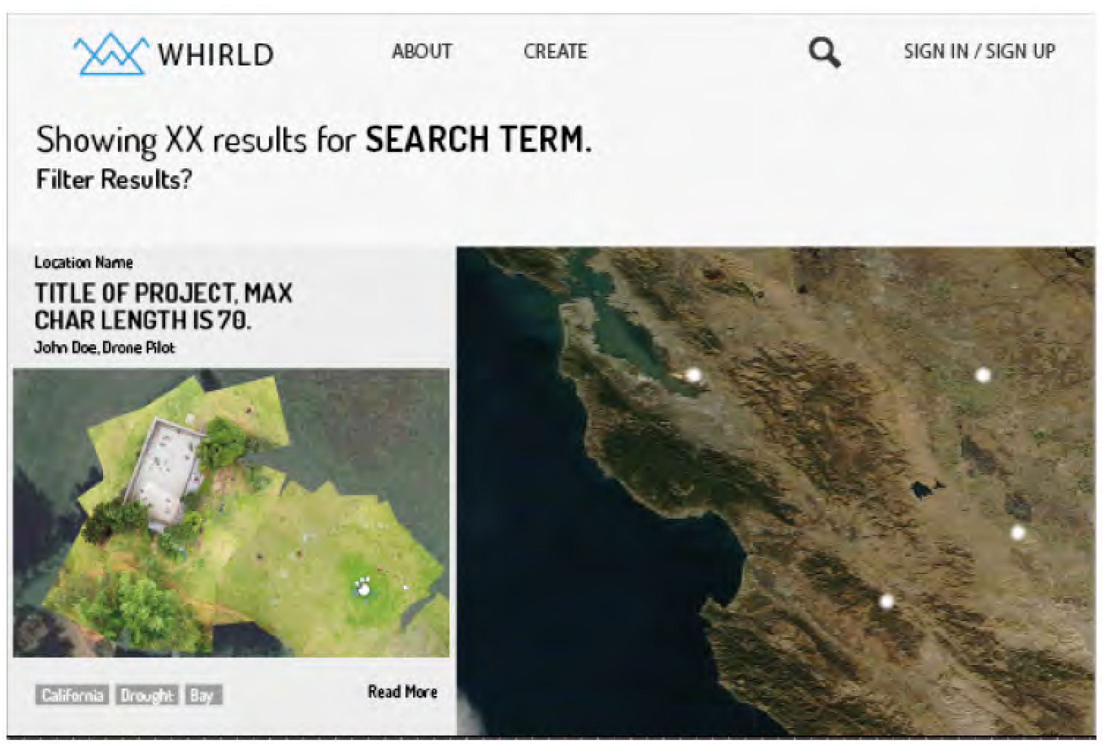
We proposed building the metaphors of image stitching and mapmaking directly into the home page, as we suggested that as the homepage's splash screen loaded, bits and pieces of the aerial image could slide into place and stitch together. Our research from Mapknitter had suggested that providing a suggestion of how easily the tool functioned would prevent users from being intimidated by the amount of work it might

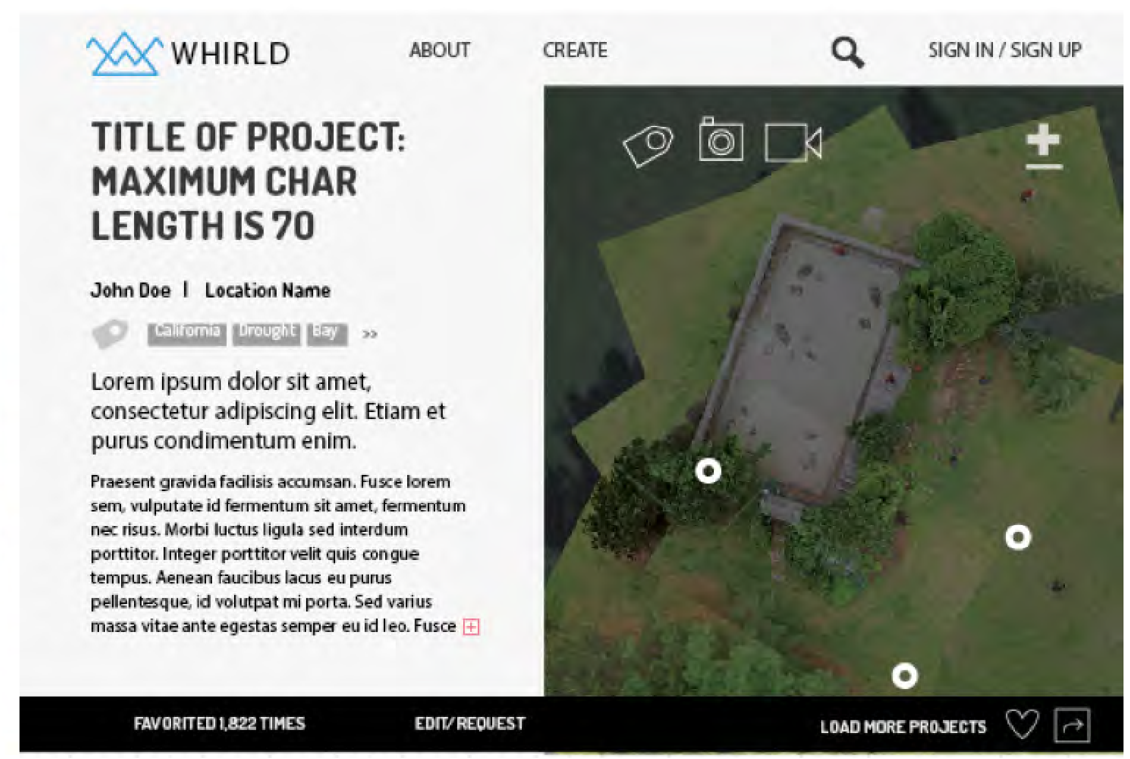


Paper prototypes emphasized the importance of aesthetics to the projects, and the similarities and contrasts between dashboard and storytelling approaches make to create a map. And the emphasis in these designs on sharing, rating and commenting on projects came from our research on citizen science and how to build a community of active users.

As our designs advanced we began to scale down some of the mess of information and features that had been proposed in initial paper prototypes. By working in Adobe Illustrator, we were also able to get a crisper look and feel that helped us imagine the user actually interface with the platform through a web browser. This approach also emphasized the need to determine aspects of the interface that at first had seemed small but were important parts of the search and discovery process. We began to discuss issues like "What filters would be allowed on a search?" and "How would a user move back and forth from a project page to search results?" As we moved more into the details, we returned to our research on other software in these spaces, often incorporating approaches from multiple tools. for instance, we tried to join iNaturalist's ability to share and encourage contributions with AirBnb's beautiful blending of spatial information and maps with feature information and photos.

We continuously prototyped in Illustrator, advancing our designs and how specific interactions would function before adding them into the software development plan





DEVELOPMENT

Our development approach connected two goals. First, we wanted to build on Mapknitter and contribute to Public Lab and the open source drone and mapping communities. Second, we wanted to introduce features that would extend opportunities for collaboration and turn Mapknitter into a larger platform. As such, we worked from the existing technical implementation of Mapknitter and from the best practices for interactive, responsive web platforms.

We prioritized the development of a prototype that allowed users to take full advantage of the key interactions (such as uploading images, building a map and editing someone else's project). We lowered prioritization of features that would be needed for a full scale implementation but which users would intuitively understand (such as fully deploying accounts and authentication). And we built Whirld to be scalable wherever feasible.

Mapknitter was first developed by Jeff Warren while at MIT Media Lab. As an open source project, it has had contributors from the Grassroots Mapping/Public Lab over the past six years. It is built on Ruby on Rails and relies on Javascript's open source Leaflet for basic map functions. Mapknitter version 2.0 was released in February, 2015 as we began development.[28] It offered some new features that were valuable for our project, including automated GPS placement of images onto the basemap.

We wanted to build more features into MapKnitter. To facilitate analysis of change over time, we developed one module with that applied the Knight Foundation's Juxtapose [29] tool.

New features for integration with Mapknitter itself were also developed on top of Leaflet. The Leaflet Draw[30] plugin was integrated to allow users to draw flight paths and link to the YouTube API to show their videos. Leaflet Slider[31] was integrated to allow effective comparisons over time. Leaflet Animated Marker was synced with the YouTube API and Leaflet Draw to allow users to compare flight paths with video footage. [32] And we incorporated Stamen Design's base maps into Leaflet, providing more options to users for customizing their projects.

As previously discussed, we wanted our our app to store, index, search, arrange, and present a rich set of data to users. The Mapknitter 2.0 framework only allowed users to upload and arrange aerial images on a leaflet map. It used a limited SQL query as its overarching search function and its interface was branded specifically to serve the needs of the Public Lab. As result, we decided to extracted MapKnitter's aerial map making functionality out of the larger codebase and integrated into our web application rather than build upon MapKnitter's existing framework.

We used Ruby on Rails and MYSQL to implement the backend of our of our application. We chose to use Rails as the backend framework because it allowed us to seamlessly integrate the existing Mapknitter code without much reworking. We also employed the the use of JQuery and Ajax in to create a more interactive experience for the user. jQuery helped us to listen and appropriately respond to the user's actions. Ajax allowed us to to seamlessly post data from the client to the server and return the the response the user without redirecting the user away from the

28. Warren, Jeff. Announcing MapKnitter 2.0 <http://publiclab.org/notes/warren/02-13-2015/announcing-mapknitter-2-0>
29. Knight Foundation. JuxtaposeJS. <http://juxtapose.knightlab.com/>
30. Toye, Jacob. Leaflet Draw. <https://github.com/Leaflet/Leaflet.draw>
31. Wilhelm, Dennis. Leaflet Slider. <https://github.com/dwilhelm89/LeafletSlider>
32. Ogle, Aaron. Animated Marker. <https://github.com/openplans/Leaflet.AnimatedMarker>

page. jQuery and Ajax were particularly helpful in developing interactive project creation and editing experiences. Since we wanted to support and modular design and allow the user to customize the the layout of his or her project, we had to develop a flexible way to pass the user's uploaded data from the client to the server. To achieve the desired result, we used jQuery's "drag and drop" function; After uploading an image, the can user click an image and drag it into a particular project module. jQuery listens for the object that user has selected and the corresponding project module that the user drops the object into. An ajax call posts the resulting association to the server, thus saving the association in the mysql database.

We also had a number of micro interactions in our application such as autocomplete forms, comments and liking features that involved small data exchanges between the client and the server. We needed to post the this data to the server without reloading the the whole page. Again, we used jQuery and Ajax to pass this data from the client to the server and then updated the DOM with the server's response using jQuery.

For our app's search feature, we implemented an ElasticSearch server. ElasticSearch is an open source, full-text search engine with schema-free JSON documents and a RESTFul interface. Specifically, ElasticSearch handles the complexities of conducting simple search and fuzzy match search (aka retrieves terms that aren't a perfect match to the query string), as well as provide a way to perform complex filtering and sorting of search results. In effort to provide a way for app users to narrow their search results, we used ElasticSearch's filtering capabilities to filter by geographic distance around a centroid point. For instance, users are able to search for projects that exist within a 100 mile radius of a specified location.

Also to note, we chose ElasticSearch over other search engines because of its its ability to scale elegantly as our our application's data grows. ElasticSearch is a distributed engine: each index can be split into "shards" (aka distributed pieces) that be distributed over several machines. Distributing ElasticSearch shards over several servers enable ElasticSearch to find relevant search results more quickly than if stored in a single instance. For app, we did not implement ElasticSearch's distributed server capabilities, however, it would be possible to do in the future as our web app's data grows.

In an effort to facilitate collaboration, our app attempts to help users discover projects as well as other users that are on our platform. First, we implement a nearby function to suggest other users and projects that a user might find interesting. For example, at the bottom of a project page, we present a user with other projects that exist in a 100 mile radius of the project that he or she is currently viewing. Next, we also implemented a recommendation server to provide users with recommended contented. We used a redis (a data structure) server and the rails recommendation library, recommendable[33] to serve recommended content to the user. The commendable library use Jaccard similarity and collaborative filtering to calculate and find recommended objects for a user.

We also identified the image uploading process as a pain point for potential users. To improve the image uploading processs, we developed a machine learning tool to classify images as aerial (for

33. "Celis, David · Github." 2012. http://davidcelis.github.com/recommendable
34. "Theano/Theano · GitHub." 2011. 4 May. 2015 <https://github.com/Theano/Theano>

placement on a map) or non-aerial (such as photos of people or of the horizon). Distinguishing aerial imagery from non-aerial imagery was done using the Theano framework for deep learning in Python. While several deep learning frameworks exist, we chose Theano due to its higher level of customization and flexibility.

To classify aerial from nonaerial images, a 3 layer LeNet convolutional network was trained on a dataset of 11,312 images created by processing 21 videos from assorted drone models from youtube.com and hand collected data from a DJI 2 drone from local regions into 5656 photos, which were then cut into 2 square images. All data were labeled by hand. Labeling in some instances was ambiguous due to the prevalence of images that were mostly aerial, but also included a small amount of the horizon line or sky due to camera rotation. Images that were ambiguous for a human were removed from the set, while any that could be rectified by Mapknitter into a usable map without cropping out patches of sky were labeled as aerial.[35] The classifier was trained on 38% of the data, with 47% validation set, and 15% test, using 200 epochs, a batch size of 20, and a learning rate of 0.1. The best score was 91.02% accuracy.

Although mapmaking was one of the primary goals of creating the platform, photos of people represent a significant portion of the photos on many of the most widely used social media platforms, including facebook, instagram, and twitter. For this reason, we considered it relevant to include a face classifier to separate images of people from images without faces. In part, this was to aid users who may want to collect both mapmaking data and images for sharing on social media in the same step, but may not want to spend the time to search for a few images of friends mixed in with a large quantity of terrain images. Citizen

35. LeCun, Yann, et al. "Comparison of learning algorithms for handwritten digit recognition." International conference on artificial neural networks. Vol. 60. 1995.

science activities as social events seems to be a common motivating factor discussed in some of the meetup groups that we visited, so we anticipate that data collection in the field may be mixed with family photos, selfies, and team photos. For this implementation, we used the pre-trained cascade classifier using Haar-like features, trained on faces, from OpenCV, a python framework for Computer Vision.[36]

Another potential pain point was the issue of radial distortion, which creates the bubbled out effect in an image, resembling a fisheye. Radial distortion (specifically barrel distortion) is a common issue in drone photography. Barrel distortion is created due to a discrepancy between the field of view of the lens and image sensor size, which causes coordinates in an image to be displaced away from the center of the image based on radial distance.[37] This effect gives drone collected images a distinctive look, which may please some enthusiasts but would alienate certain photographers who wish to use drones for artistic or commercial imagery. To address this, we offered users the ability do a rewarping of the images based on one instance of the OpenCV library's camera matrix implementation.[38] Rewarping is currently possible for images from lenses similar to that of the DJI Phantom 2 and future expansion of the platform could easily incorporate parameters for other models.

As discussed, Whirld is not designed for a single, specific user community. While we developed features that we knew members of the drone,

36. "OpenCV | OpenCV." 2010. 4 May. 2015 <http://opencv.org/>
37. Szeliski, Richard. Computer vision: algorithms and applications. Springer Science & Business Media, 2010.
38. "OpenCV | OpenCV." 2010. 4 May. 2015 <http://opencv.org/>

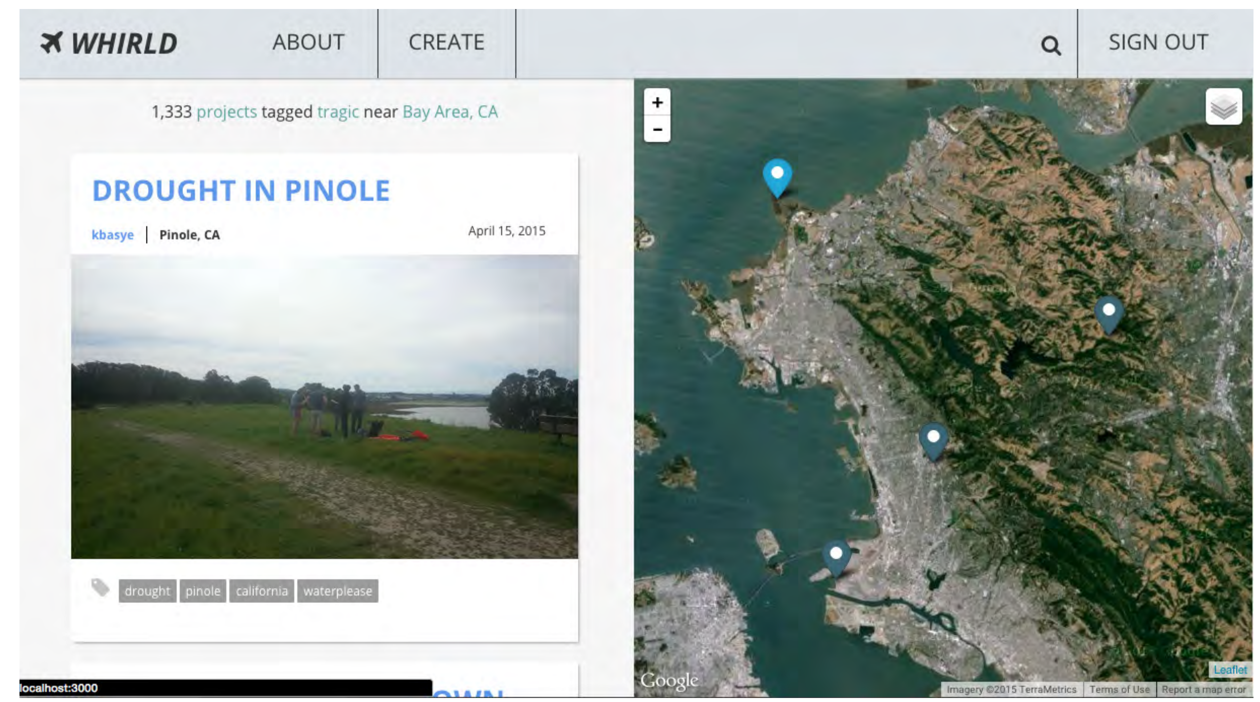
mapping or citizen science community would be familiar with, Whirld could only be successful as a platform accessible to users outside of these specific communities. As such, we tested and solicited feedback from both these communities and from people with no connections to drones, mapping or science. Our results gave us critical feedback on our prototype that we were able to incorporate into the current version of Whirld and identify as possible future developments for Whirld.

Rapid Iterative Testing Evaluation (RITE)

Our initial search design showed a split screen consisting of query results in list form and plotted by location on a map.

This design allows users to hover over the plotted results on the right and see a preview of the correlating project at left. The presentation choice was intended to provide users with access to a more immediate overview of the breadth and geographic distribution of search results. Simultaneously, the juxtaposition of the list view offered users the chance to explore the results without obstructing the map. Each result in the list view was presented as a project preview, highlighting the most salient elements of a project — title, featured photo, tags, and author. It was our belief that this layout would reduce the noisiness in products such as Google Earth pro and facilitate better understanding and discovery of the data points represented on the map.

We decided to test the rigor of our geographic search interface theories with the RITE method, giving users the task of gathering information about parks in California in our interface. We recruited users from among our classmates at the I School, and we selected three volunteers based on their interest and availability. All users successfully found our omnipresent search bar, but each grew less assured of their path upon reaching the search results page. Ultimately, our evaluation demonstrated that our interface for geolocation search was weakened by significant assumptions, which are detailed below.



An example of a prior visual and interaction design system for the search functionality.

First, in dedicating the same amount of space to list view and map view, we presumed that both are of equal importance to the understanding of search results. In reality, users entirely ignored the map until directed to explore it.

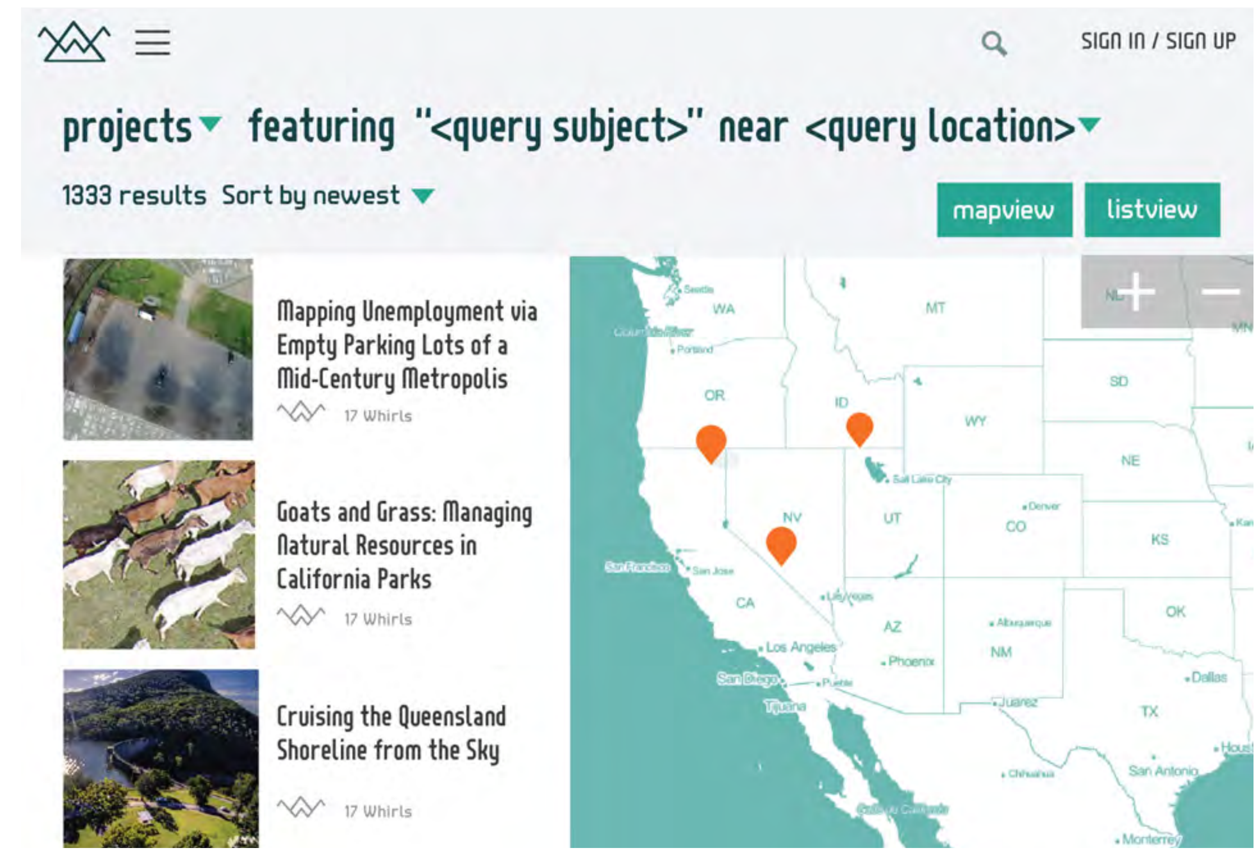
Second, when the users did explore the map, they were unclear about what was being shown. The map was designed to automatically scale to focus on the furthest boundary of results, and though our users were very familiar with the geography of California, one noted, “Well, if I didn’t live here, I wouldn’t know that I was seeing.” Completely contrary to our goal of orienting the user, our restrictive geography could cause a place to become alien in its dissociation from familiar geographic context clues.

Third, we regrettably noticed that our choice of a simple, traditional blue and green base map for displaying results was confusing to user within the parameters of our specific tasks. One user noted the green on the map and said, “Oh . . . Are these the parks? Wait, no . . .” In this case, we assumed that the default design of blue and green when representing water and land symbols was clear and sufficient, but given we tasked users to search for parks, a natural resource, it is understandable that these colors acquire a different interpretation.

Finally, though the user’s query and the total number of matching results were stated on the search results page, users often missed these elements due to the size of the typography.This was a major issue, as users felt uncertain that additional results were displayed beyond the first visible project on the left side of the page.

Our final iteration was a response to the issues we discovered during the RITE analysis.

We redesigned the search query to fit a natural language paradigm, more results displayed on the first page, the option to view the results on a map view or separately as list, and the ability to redo the search with different parameters (e.g. search by user as opposed to project).



The information architecture of the update design shows more context around the results.

RESULTS

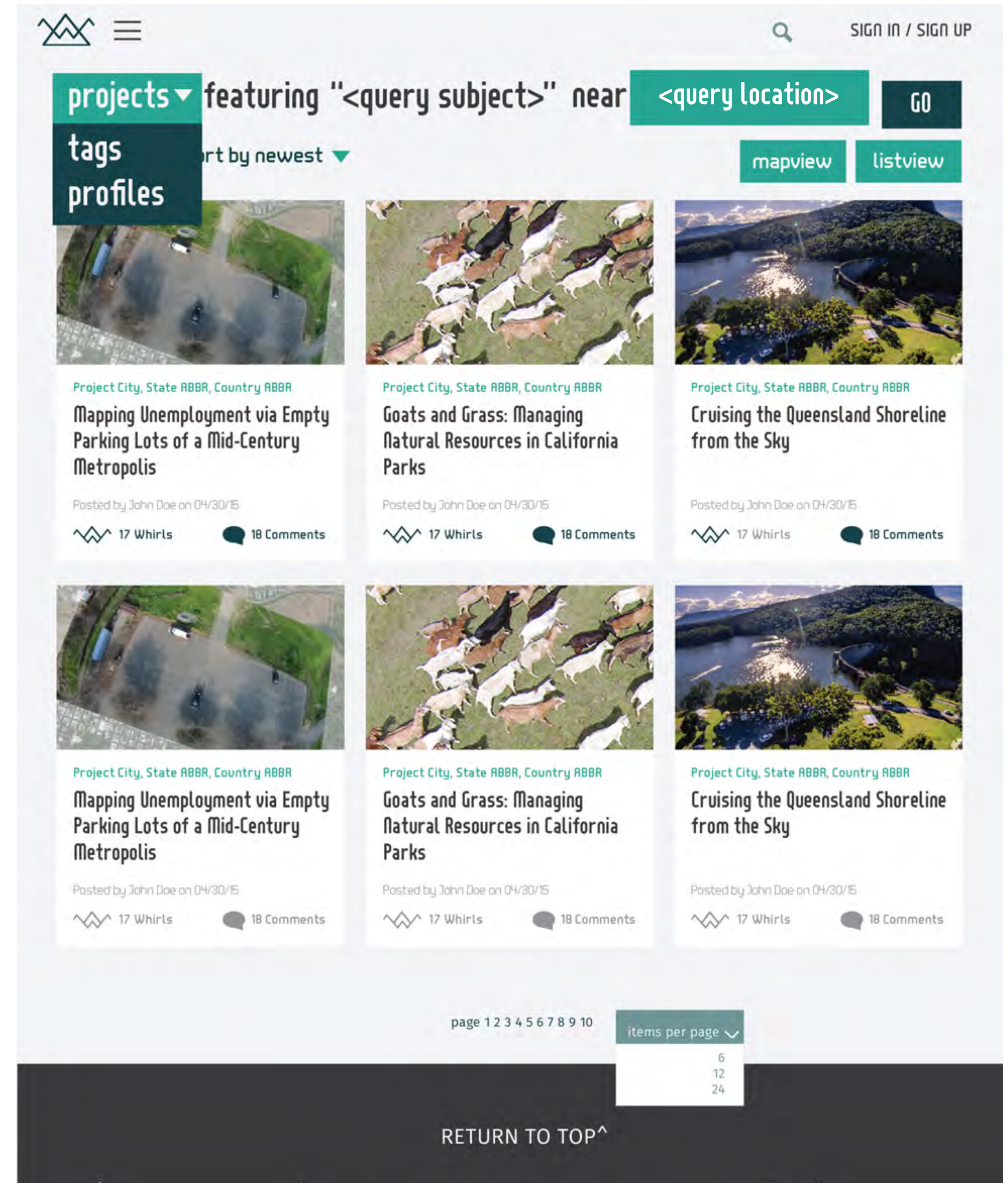
Whirld's landing page provides users with a simple introduction to the platform. It immediately emphasizes the ability to create maps from aerial imagery and encourages the user to search and projects. While search is powerful enough to incorporate searches across projects and modules by keywords, tags and location, it is simple enough to facilitate the simple kind of keyword search that a user might start with.

Other stuff about having top users, most liked projects etc on there as we get that finalized.

Upon searching, the user is able to easily filter by more specific features, but search maintains a natural language approach to make the search experience as intuitive as possible to users. As a platform, Whirld could house tens of thousands of projects, and this approach to filtering by keywords, tags and location helps users quickly toggle between "querying/searching and browsing/navigating" information seeking strategies.[39] Whirld's search approach allows for rapid query formulation and presentation of results, while offering automatic search refinement (via autocomplete and suggested tags) or manual search refinement (by filtering results after the search). Autocompletion and tag suggestion based on existing projects on the platform was critical to emphasize a browsing approach to search and encourage exploration over more directed searches. Contributors to a project wouldn't need to be searching for it; they would know the title and be able to find it immediately via autocomplete or clicking the link on their profile page. Considering the diverse user base Whirld is was designed for, emphasizing browsing over directed search will facilitate users discovering new projects and possible collaboration opportunities.

The search results are split into a list view and a map view. Based on our research of existing platforms that show results by location and from feedback during user testing, the list view drives what is shown on the map, rather than the other way around or a two way relationship.

39. Hearts, Marti. Search User Interfaces. Section 3.5.3 Cambridge University Press, 2009. Accessed at <http://searchuserinterfaces.com/book/sui_ch3_models_of_information_seeking.html#section_3.5>



Refinements to search included an added option to view the results on a map or as a list. Pagination was also introduced as secondary navigational element.

The project page sits at the center of Whirld. As Whirld was designed to facilitate contributions from many users with different interests, backgrounds, skillsets and tools, projects were designed to minimize the barriers to entry for any form of contribution.

Project page: Opening headline, tags, user-generated map and video.

Project page: Body text of project, tags, user-generated photos.

Images are automatically classified as aerial or non-aerial and as having people in them upon upload, eliminating the hurdle for a drone pilot of sorting through dozens of photos to figure out which might be relevant for building a map.

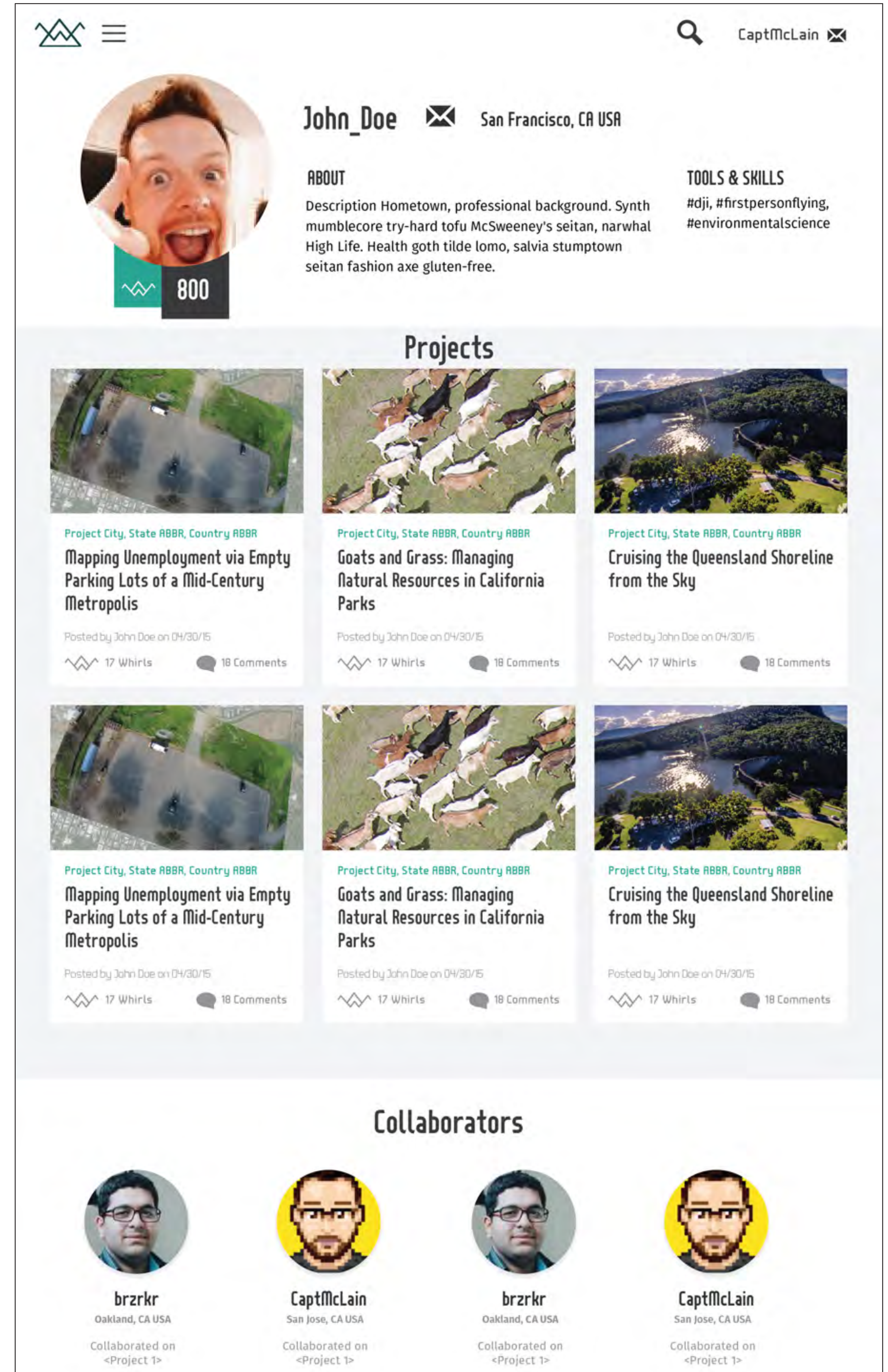
Six modules were developed to contribute content to a project:

- A map, building on top of Mapknitter, where users can drop aerial images, stitch these photos together, draw drone flight paths and link videos.
- A video, embedded from YouTube
- A photoset, as most projects that use aerial imagery and maps would be augmented by other photos, whether from a drone or handheld
- Text descriptions, where users can submit text content that provides analysis or background on the project
- Photo comparisons, where users can clearly compare two photos, which is particularly useful for projects that show change over time
- Text and photo combinations

These modules offer many ways to contribute and minimizes the barriers to entry for different user bases. Drone pilots can upload their photos and have them automatically classified without having to deal with actually building a map. They can link to videos and draw their flight paths, providing a record where they can share their drone experiences but without being forced to expend effort the aspects of a project they might not feel passionately about. Users interested in mapmaking can take those photos and stitch together maps in Mapknitter. Experts about the type of project can contribute other photos or text, whether they are community members who live near the project site or they are scientists who can provide insight into what a set of maps, videos and photos might say about a landscape or environment.

Users own projects that they create, but anyone viewing a project can request access to gain edit rights to a project. This relies on establishing a trusting community where collaboration and peer production is encouraged, and quality of contributions is monitored by peers in the community.To set up this type of community, we developed a profile page that would immediately let a user's identify both high level information and specifics about a user. At a glance, a user can see:

- How many projects someone contributed to
- What type of assets (e.g. drone videos, text, other photos) they contribute
- How popular those assets were (from aggregating "likes")
- Where a user is physically located
- How recently a user has been active



Profile page

FUTURE WORK

We are very lucky to have worked with a number of individuals and organizations who can immediately benefit from this work, connect it to their existing projects and build on it.

We will be submitting our results to the ACM Computer-Supported Cooperate Work and Social Computing (CSCW) Conference, to be held in San Francisco in February, 2016. We aim to present this project at the conference in order to both share the lessons we have learned and collaborate with other researchers on future applications of Whirld.

We are sharing our results with Jeff Warren, the other Mapknitter developers, and the Public Lab community. We've already shared some of our results with them and we think a number of our features, including image classification, modularity of features, and enhanced search and discovery tools will be helpful resources.

Our results have also been shared with the DIY drone community, a large base of hobbyists and enthusiasts who may be inspired by this work. We have shared our work with the Nerds for Nature Community, may further expand this project through that network. iNaturalist, for one, has been supported by Nerds for Nature and while we may not have the long term vision of Ken-Ichi, we are encouraged by iNaturalist's success.

This project will also continue within UC Berkeley. The Center for Information Technology Research in the Interest of Society (CITRIS) is currently running a number of long term projects, including AppCivist. "AppCivist provides a software platform for democratic assembly and collective action that lets users (and especially social activists) make their own applications, called Assemblies, with modular components. The components include proposal making, deliberation, versioning, voting, alerting, networking, and mapping."[40] We were fortunate enough to connect with one of the postdoctoral fellows working on the project, Cristhian Daniel Parra, and he is enthusiastic about incorporating our work into the online collaboration and mapmaking components of AppCivist. We are particularly encouraged by this as it shows yet another opportunity for aerial imagery and drone technologies to support citizen actions.

40. Holston, James. AppCivist, CITRIS, University of California, Berkeley. http://citris-uc.org/social-apps-lab/project/appcivist/

CONCLUSION

We don't know what the future of aerial imagery and drone technologies will look like. There might be negative futures. Will the skies be filled with Amazon drones coming and going with our orders, transmitting photos and videos back to Amazon's databases wherever they fly? Will police departments launch drones above crime stricken areas to automatically track crimes and pursue criminals? Will homeowners close their curtains and raise netting around their properties to prevent drones from intruding on their privacy? But there could also be positive futures for these technologies. Will drones be automatically sent to medical emergency sites and help doctors save lives via remote video? Will fleets of drones airlift supplies into natural disaster sites?

There are an incredible array of opportunities for what these technologies can be applied to. While we don't know which of these applications will be successful, Whirld can help to democratize this process, engaging more stakeholders, communities and individuals in determining what the future of our skies will be.

THANK YOU

We want to thank everyone who has helped us with this project, from our initial thoughts in October to our final submission. In particular, Coye Cheshire has been a fantastic adviser, guiding us from incoherent thoughts to our final submission, and we can't thank him enough for his support and generosity. Sorry for crashing the Phantom into the Bay....

The Public Lab community has been amazingly supportive. Many thanks to Public Lab staff, including Jeff Warren, Matthew Lippincott, and Stevie Lewis, and Public Lab contributors, including Chris Fastie, and particularly Pat Coyle, whose enthusiasm (and helium!) gave us a lift.

We've found the drone community welcoming to our ideas and happy to help. Many thanks to Erich Botonio, Mike Ocasio, the Game of Drones Meetup Group, Ragi Burham and AmigoCloud, and the Silicon Valley chapter of AUVSI.

Nerds for Nature was a great help in identifying use cases for our project and providing valuable feedback. Many thanks to Dan Rademacher, Ken McGary, and everyone in the Nerds for Nature Meetup group. And thanks to Ken-ichi Ueda, Nate Agrin, and Jessica Kline for your work on iNaturalist at the I School, as well as everyone who was worked at iNaturalist since. We at first were hesitant to look too much at previous I School projects, particularly those explicitly in citizen science, which we were scared of. But we found ourselves returning again and again to your work as a resource and a comparison point.

Thank you Alan McConchie and everyone we met in Stamen Design for your feedback and thoughts on the design challenges of this project.

We couldn't have done this without getting some fantastic drone footage. Thanks to Mark Honer from DHTV Digital, Riley Peterson from DroneStar, Sabrina Lockey from Jukin Media, Aaron Jaffe from Flyral Imaging, Ollie Pritchard-Barrett from Oil & Earth, Steve Diddle from Drone Outlook, and Matt Robinson from AerialExploration.

Thanks to Orien Richmond, at US Fish and Wildlife, Sharon Dulava and Chris Muhl from Humboldt State, for giving us information, feedback and inspiration as we grasped for ideas of where this project would go.

The UC Berkeley community has been a great help and we hope that folks will carry some of this research forward in their own projects. Thanks to Steve Weber here at the I School for his valuable feedback as we tried to find a balance between collaboration and marketplace activities. Additionally, James Fahn from the Graduate School of Journalism, Nancy Thomas (and everyone involved in Geolunch) from the Geospatial Innovation Facility, and Cristhian Daniel Parra from CITRIS, helped inform our research decisions and we hope that our project will be valuable for their own work.

APPENDIX

Appendix A: Usability Tests

Interactive Prototype Testing Script
Certain parts heavily adapted from Goodman et al., Kindle location 5098.

Introduction (5 minutes)

Hi, welcome, thank you for coming in today. How's it going?

I'm _____. I am part of a group at the I School who is building a platform called Whirld.

Whirld allows users to:

upload aerial photos and video

create a map from their own aerial photos

add multimedia to a base map

aggregate media into projects on a subject of interest

observe change over time in a specific location

discover people with shared interests and support collaboration

Today we're specifically interested in how our platform is performing in permitting users to search and view this diverse information. We've brought you here to see what you think of it, what features seems to work for you, what doesn't, etc.

This is ________, who will be observing what we're doing today. We're going to be recording audio of what happens here today and taking video of the screen interactions. The audio is used so we can capture your comments verbatim for our research. The video is for analysis only, and we do this primarily so I can concentrate on talking to you instead of scribbling notes on what is happening on screen. It will only be seen by me, ____[observer]____, and our other three team members. It's strictly for research and not for public broadcast or promotion.

This evaluation should take about 30 minutes. The procedure we're going to do will go like this:

I will ask you to talk aloud as you explore two features of the interface: the search page and the project page.

I will begin by asking you to complete a task using the search interface. Once you have completed the search task you will have some time for open exploration of the project interface.

Finally, toward the end I will ask you some questions about your experience and you will have the opportunity to offer any additional feedback about the exercise.

Please remember that any challenges you come across in navigating the interface are not due to any deficit on your part. I encourage you to point out such obstacles, and you may also ask me for assistance if anything is unclear.

Any questions about any of that?

Now I'd like to read you what's called a statement of informed consent. It's a standard thing I read to everyone I interview. It sets out your rights as a person who is participating in this kind of research.

<<Hands consent sheet to participant.>>

As a participant in this research:

You may stop at any time.

You may ask questions at any time.

You may leave at any time.

There is no deception involved.

Your answers are kept confidential.

Any questions before we begin?

Search Task: Find a project about parks in California
Goal: Discover the primary and secondary tools utilized in a multidimensional search

What do they want to see in the results? What makes them decide to click on one over another?

What to do with lots of results? What do they expect to happen (should map fit more results when you load more)?

INTERVIEWER : Imagine you are looking for information about parks in California. How would you search for this?

[Interviewer should observe and record the following, asking these questions explicitly when answers are not evident through the user's actions]

What type of term(s) does the user enter for a query? E.g. location, descriptors. What level of granularity? (State, City, ZIP?)

Which, if any, filters are most useful for refining information?
<<Ex: date of project, date of upload, images, text, tags?
Do any filter terms cause confusion?>>

Are users satisfied with exploring the range of returned results, or do they wish to sort results into a more explicit hierarchy?
<<Ex: "Showing [100 results] for [parks] in [California] .
Ordered by [date]." >>

What scope do users expect to find in the search results? (project, photo, video?) Does the actual scope returned match user expectations?

Is the absence of projects informative to the user? Put another way, do people want to see labels for locations that do not have associated projects?

<<Ex: Point Pinole should show up in a query for parks in California, but is it helpful it highlight all parks in California on the map and then emphasize those parks that have a project associated?>>

Project Task : Locate specific links and features
Goal: Evaluate design, information architecture

INTERVIEWER : This is an example of a project page. A project is a combination of photos, videos, and text that are tied to a specific geographic boundary. Users can create a project about a location that interests them, and they also comment on other projects or ask to contribute to a project. Here we see one user's project about Point Pinole in California. I'd like you to scan through it and tell me a bit about it.

What is the location of the project?

Who is the author? What is the author's location?
<< ***Note: The current design for the project prototype shows the author's location next to his name, but this could be misinterpreted as the project location.***>>

Thanks. I'd like you to first point to the different sections of the site where you would expect the following actions, and then you may click on those sections to see if they live up to your expectation. This page is still under development, so if some links are not live yet, just tell us.

Can you tell me how you would contact the author?

Imagine you would like to comment on the project. Where would you do that?

Imagine you would like to contribute a photo to a project. How would you do that?

What do you expect of the favorite button? (access to in-site bookmark list of projects they've favorited? uptick of numbers as in like or upvote paradigm?)

<Interviewer should observe and record the following, asking these

questions explicitly when answers are not evident through the user's actions>

Are users inclined to find out more about the author?

Do users utilize tags? How? (clicking, attempting to add a tag, etc.)

Do users understand how to access video?

What do users expect of the edit button?

EXIT INTERVIEW

Whirld Related - General

What types of projects could be created or hosted using Whirld? What would motivate you to create or contribute to a project?

If you were to create a profile on the site, how would you want to describe your role in a way that would help people discover your profile? Example: drone pilot, scientist, amateur naturalist, designer, hardware engineer, etc.

What do you see as the major limitations of the platform? The benefits?

Drones + Society

Do you believe that hobbyist drones can be useful for reliable, high quality scientific data collection? When you hear about these consumer grade drones, do you imagine people using them as toys or as tools?

Many people have voiced concern over privacy issues with digital media – both for physical artifacts like Google Glass and over the quality of privacy and data security on apps and websites. Do you have any concerns over the use of hobbyist drones in this area?

What capabilities would you most like to see in drones? (Not taking into account the limitations of current technologies).

Appendix B: User Survey

Drone Use and Collaborative Work Survey

Please review the consent form at the link and click consent if you agree to do the study. https://docs.google.com/document/d/15bkrWZ4Vh6IwWRN4988KPFrfSjb_sD23EcCRbrGVONU/edit?usp=sharing

I consent

I do not consent

Do you currently own a drone/uav?

Yes, I own more than one

No, but I am planning on buying one in the next year

Yes, I own one

No, and I do not plan to buy one in the next year

If you answered yes to the question above or are planning to buy a drone, what model(s) do you own or plan to purchase?

Leave blank if you do not own a drone or plan on purchasing one.

____

As a citizen, I feel motivated to participate in local projects and activities that benefit the community.

Strongly disagree 1 2 3 4 5 Strongly agree

Which social media platforms (if any) do you regularly use?

*regular = 1 or more times per week

I rarely use social media platforms

Twitter

Facebook

Instagram

Yelp

Pinterest

Linkedin

Google+

Foursquare

Wordpress, Blogspot, or similar

Flickr

Other: ________________

What factors motivate you to participate in any collaboration or project?

Examples can include: citizen science efforts, community service, workshops, hackathons, research or any type of purposeful group activity.

Networking

Personal values/beliefs

Opportunity to teach others

Entertainment

Prestige or challenge of the activity

Resume/portfolio building

Opportunity to meet new friends

Being a part of a meaningful project

Monetary compensation

Convenience of location (local)

Other: _______________

I consider myself to have some level of proficiency in some scientific field (including physical, biological, and environmental sciences)

*0 = limited knowledge/exposure, 3 = average knowledge of a college graduate science major, 5 = professional scientist or similar experience

Strongly disagree 1 2 3 4 5 Strongly agree

I enjoy working with people in different professions.

Strongly disagree 1 2 3 4 5 Strongly agree

I am interested in working with projects involving hardware, sensors, or other types of electronic media.

Strongly disagree 1 2 3 4 5 Strongly agree

I am drawn to browse images on social media or image sharing websites because:

I rarely browse images on social media or image sharing websites

To gain awareness of current events

To see what my friends are doing

To view specific places before I visit them (restaurants, parks, etc)

Out of boredom

To look at aesthetically appealing images of scenery, people, food, etc

Out of convenience (I am browsing textual content and will look at related photos)

Other: ________________

I enjoy taking photos and sharing them with friends, family, and/or the community.

Strongly disagree 1 2 3 4 5 Strongly agree