Volunteered Drone Imagery: Challenges and constraints to the development of an open shared image repository

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Abstract

Orthorectified imagery is valuable for a wide range of initiatives including environmental change detection, planning, and disaster response. Obtaining aerial imagery at high temporal and spatial scale has traditionally been expensive. Due to lower costs and improved ease of use, unmanned aerial vehicles (UAVs) have been increasingly prevalent. This presents an opportunity to share images as part of participatory geographic information systems initiatives similar to OpenStreetMap. We outline a workflow to generate maps from UAV aerial images. We then present a characterization of software platforms currently available to aide development of maps from UAV imagery, defined by type of service, whether imagery hosting or data processing. From this analysis we identify existing barriers to imagery sharing, including data licensing, data quality, and user engagement.

1. Introduction

Timely, high-resolution aerial imagery can be valuable for recording and monitoring changes in an environment. This imagery has been recognized as critical to evaluate terrain after a natural disaster [1]–[4] as well as measure environmental changes including agriculture and forestry [5]–[7]. Until recently, accessing this information has required specialized equipment and skills. The high cost of aerial photography required for monitoring small-scale phenomena presents a barrier to accessing imagery and maps at appropriate spatial and temporal scale. Barriers to accessing customized aerial imagery are rapidly dissolving due to the decreasing price of unmanned aerial vehicles (UAVs) and Unmanned Aerial Systems (UAS). UAS include the use of UAVs, associated hardware (ex. GPS and other sensors) and software (ex. imagery processing and autopilot) required to operate and create products such as maps [8], [9]. As UAS are growing in popularity, there is a surge of actors, particularly from the private sector, including vehicle hardware developers and software companies, with services aimed at reducing even further still the entrance costs to this field. We are witnessing the leading edge of companies building business models that support UAS.

One significant output from this increase in UAS availability is a global supply of aerial imagery. This raises questions about the collective use of imagery produced from many privately-owned UAVs, particularly if it can be stitched together to provide a user-generated, frequently updated, high resolution imagery map. There are many practical needs that this type of product could fill. For example, humanitarian response organizations could have access to up-to-date imagery of disaster zones more quickly [10]–[13]. Private sector companies could build value added services on top of this living imagery set. Governments could access user-generated imagery to ground truth their infrastructure datasets, reducing the need for costly site visits, particularly in remote or rapidly changing areas. Despite these benefits of an open, accessible user-generated imagery map of the world, there is a host of challenges to its realization.

The main research goal of this paper is to provide an initial assessment of the potential application of existing UAV image collection methods for the creation of an open, shared user-generated imagery library. We aim to trace the integration of two emerging methodologies of citizen science and UAVs, assessing the challenges to the implementation of an open, shared imagery model. We approach this research goal in three ways. First is to present a baseline characterization of a UAV mapping workflow, that is, the specific components of acquisition, stitching, analysis, and sharing of UAV imagery. This workflow forms the core data collection task that would feed into a user-contributed imagery repository, and provides a framing for how citizen science and UAVs are integrated. Second is to present current initiatives, whether for profit or not-for-profit, that facilitate the gathering, hosting, analysis, and sharing of user-contributed UAV imagery. This is not a

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complete census of the UAV ecosystem, but rather a targeted selection of existing, publicly-discoverable initiatives that directly support user-contribution of UAV imagery. The third objective of this paper is to identify key challenges to the development of an open, volunteered imagery repository where private UAVs are used to collect imagery that is contributed easily and seamlessly for the collective reuse by other parties. We begin by reviewing foundational concepts to which this paper contributes, including volunteered geographic information (VGI) and citizen science. We focus on the gap in VGI and citizen science in that data contributions are in the form of vectors, and UAV present an opportunity for VGI in the form of aerial imagery.

1.1 Volunteered Geographic Information

Now, arguably, anyone with a smartphone and associated applications can contribute information to a map in a variety of ways. This makes participatory mapping projects more feasible and accessible in the form of VGI [14]–[19]. VGI can be an active or passive process and data can be spatial or a-spatial and be variable in terms of key attributes like format, description and quality [20].

VGI is often referred to as an outcome of ‘the rise of the amateur’, a movement heralded for its promise to afford opportunities to collect data from demographically varied and geographically dispersed perspectives [15], [18], [19], [21], [22]. VGI can be used to fill in areas on a map that are lacking information and can be used to complement existing data collection methods [23]. This new means of spatial data collection is shifting the role of knowledge production away from trained GIS professionals [21], opening up research avenues around non-expert spatial data capture, creation, analysis, and sharing [15], [24]–[28].

VGI are typically contributed in the form of points, lines and polygons (vectors) added to a map with associated text and/or geotagged media on top of a base map. A base map typically offers traditional aerial imagery, or satellite maps, a more traditional road map and often other versions of standard base maps where users remain restricted to the fixed view of the world offered by the base map provider. The imagery offered is fixed by the time of day that the satellite or plane passed over and captured an image, creating a time lag with reality that can impact the utility of this imagery for many purposes. Though this imagery is constantly updated, the end user has no input to this process, and unlike VGI, to date there are limited opportunities for the non-expert user to contribute aerial photography.

1.2 Citizen Science

Citizen science initiatives include the incorporation of citizen efforts into the scientific process, primarily via data collection, where interested citizens volunteer their time and observations [29]. Much like with VGI, mobile devices can be used to collect observations. This has been revolutionary for the field of Geographic Information Science [30], [31], and researchers are utilizing these techniques to monitor a wide range of phenomenon [32], [19], [33]. The citizen science movement has largely embraced VGI collection methods, applying them in many contexts. Well-known examples include the Audubon’s Christmas Bird Count and online efforts like Zooniverse which hosts a wide range of citizen science projects in one place. Citizen science and VGI have also been used for search and rescue efforts during post-disaster management efforts [3], [34]–[37]. Humanitarian OSM (HOT) is a special effort that facilitates map efforts in areas affected by disaster [38], [39].

Concerns regarding the inclusion of data collected by citizens in scientific projects relate to the quality of the data contributed, questioning its accuracy and precision [32], [17], [40], [41]. Ethical considerations related to VGI and citizen science include passive or ambient versus active participation or data collection [42], [26], [43], [44]. Additionally, scholars have investigated motivations for participation in terms of VGI and other forms of spatial media [45], [44], [46]. Acknowledged barriers to participation in citizen science include digital and sometimes spatial literacy as well as access to technology and simply time to participate [30], [26], [46], [47]. Despite these barriers, citizen science remains a growing field.

1.3 Examples of Citizen-based Aerial Imagery Mapping

Citizen scientists and VGI have embraced the use and creation of aerial imagery. An early instance of aerial imagery mapping by private citizens occurred in Lima, Peru [48], [49] to define local needs and improve balloon and kite imaging techniques. Workshops were used to involve the local youth in the map-making process. The project emerged as an effort in providing an alternative to “tightly controlled” spatial data, much like OSM but with a focus on raster data instead of vector [48], [49]. Up-to-date maps of informal settlements in Lima were produced using balloon and kite imagery, and it was proposed that these maps be used for research and planning, decision making, public works projects, and land-use discussions [49]. The mapped imagery had a significantly higher resolution and was more current than existing satellite/aerial imagery [68], [70]. The quality of the resulting aerial imagery was so high that Google integrated it into their own products (the imagery was published in the public domain, requiring no permissions for downloading and republishing) [49], [51], [52].

Another example where homemade aerial imagery helped with citizen science occurred during the Deepwater Horizon Oil Spill (also referred to as the BP Oil Spill) that devastated ecosystems in the Gulf of Mexico in 2010. Balloon and kite mapping, led by the Public Laboratory for Open Technology and Science (PLOTS), was used to fill the gap in coverage created from a media blackout and restricted access to the impacted sites [48], [49]. This grassroots mapping produced such a wealth of imagery data, that a sorting tool (referred to as MapMill, at mapmill.org) was developed to increase the efficiency of sorting and evaluating the imagery [49]. MapMill users were asked to rank the images in terms of quality and usefulness before they were orthorectified and added to the map(s) [49]. In this event, over 100,000 images were collected, and over 80 maps were built, depicting the state of the coastline before, during, and after the oil spill disaster [53]. The maps were distributed across impacted communities to aid in community-led restoration and recovery efforts of the local environments, economies, and ecosystems [53].

Grassroots mapping via balloons, kites, and UAVs offers new ways for citizens to create their own datasets, and is one solution to issues of cost and limited access to aerial imagery [49]. The resulting data and maps from grassroots mapping efforts can be used by citizens and activist groups to build evidence for cases against large-scale environmentally destructive projects [50]. The resulting information can also be used to prove or, more likely, disprove statements made by the media about controversial issues [48], as exemplified by the grassroots mapping during the Deepwater Horizon Oil Spill to fill in gaps left by the media blackout and restricted access. Finally, the recent addition of UAVs into the grassroots mapping realm offers a unique opportunity of "repurposing military technology" for addressing community needs, enabling grassroots activism, and providing support in environmental advocacy [50].

2. UAV Mapping Workflow

We have presented evidence of the use of aerial imagery collected from citizen science and VGI. Flying a UAV and collecting imagery is only one step in terms of generating a map. There are a wide range of configurations in terms of workflows including necessary hardware and software choices to generate a map from imagery collected from a UAV. We briefly outline how aerial imagery is commonly collected, processed, and shared using UAVs. The first step is flight planning; however, we will not cover this step in detail as the focus of this paper is on data processing and sharing information, not the data acquisition itself. The workflow described here is a simplified overview. Research fields associated with environmental monitoring offer a wide range of alternative and detailed workflows [7], [10], [54], [55]. We focus on the following four steps associated with a workflow to take images from a UAV to share as maps: 1. Imagery acquisition during UAV flight; 2. Imagery stitching; 3. Imagery/Map analysis; 4. Map sharing.

2.1 Data Acquisition during flight

The first step is gathering data in the form of imagery acquisition. During a UAV flight, several images need to be taken at regular intervals to ensure that images overlap. This is critical, so that measurements between objects present in the images can be made. Broadly, this process is known as photogrammetry [56], [57]. For imagery to be usable for data analysis and map mapmaking, relevant metadata is required for imagery stitching. These metadata are inserted automatically by a microcomputer onboard a UAV. Currently, many UAV hardware manufacturers offer a Software Development Kit (SDK), making it possible for third parties to develop software systems to interface with the camera and any other onboard sensors available. This provision of SDKs is critical in that it allows for the growth of enhanced services that may be more user-friendly, reducing reliance on manufacturer default control systems. For example, SDKs can be used to develop autopilot functions that are useful for control of the flight and to ensure sufficient overlap of images.

2.2 Imagery Stitching

Once the flight and data acquisition have been completed, the second step is to amalgamate individual aerial images into a useful map, typically using a specialized form of photogrammetry to quickly stitch images together. This specialized form of photogrammetry is called Structure-from-Motion (SfM) and emerged from computer vision research [58]–[60]. The aim of computer vision is to replicate human vision through the use of computers. SfM software stitches images of the same scene from different angles, together by comparing, matching and measuring angles between objects within each image [11], [54], [58], [61].

Measurements and derivative products can be made from these stitched images, including orthophotos, and 3D scenes or videos. There is a wide range of existing tools to accomplish imagery stitching, including both open source and proprietary options. At present, existing open source SfM software is typically difficult for non-experts to use or much less efficient (in terms of processing speed and accuracy) than proprietary counterparts. This means that open source SfM software that are free of monetary cost may not be feasible options for the growing segment of the UAV community who are not proficient in command line interfaces, thus making usable SfM software inaccessible to those without financial means to purchase proprietary solutions.

2.3 Imagery/Map Analysis

In this third step, an analyst may take georeferenced, stitched images and create a map, transforming data into information. To do this, GIS functionality typically associated with desktop GIS software packages are necessary, specifically, raster data analysis. Raster to vector functionality, generating digital elevation models, and other types of classifications are also valuable and commonly used during this step. For example, in the precision agriculture industry, there are several companies developing tools to automate this process to be able to rapidly identify problems with crops so that they may be quickly addressed through improved management practices. This type of example shows how imagery and map analysis can be used to develop value-added products from aerial imagery, leading to the creation of a range of third-party options and services.

2.4 Map Sharing Platforms

The final step in a UAV mapping workflow is map sharing. Imagery can be shared as individual photos, or draped over digital elevation models. Typically, these images are shared online in an ad hoc fashion, often lacking metadata. How images are and can be shared is influenced by the first steps of the UAV workflow, including what specific products have been used. Different software systems all provide geospatial information in different ways in different coordinate systems and at different accuracies, which greatly influences how they can be used and shared. This diversity of platforms and systems has created several technical challenges in realizing a vision of an open user-generated aerial image repository. We now turn to characterizing this emerging area of services and tools, as well as focusing on key challenges to its development.

3. Methodology

For this study, we conducted a review of existing organizations who facilitate gathering, hosting, or providing user-contributed aerial imagery generated by UAV platforms. This review was conducted using public-facing internet resources provided by these organizations. A global search was completed in Google Search Engine using the following key search terms: "volunteer drone imagery," "drone citizen science," "volunteer UAV imagery," "volunteer aerial imagery," "crowdsourced drone imagery," "crowdsourced UAV imagery," "crowdsourced aerial imagery," "big aerial data," "grassroots mapping," and "grassroots UAV mapping." The search results were thoroughly examined, and often involved reading through blogs, forums, lists, and both scientific and non-scientific articles for descriptions of UAV imagery hosting and sharing services. Once specific organizations were identified, the services described and presented were assessed to determine whether they would be appropriate for inclusion. The search results were included based on a number of inclusion criteria and exclusion conditions, which are summarized in Table 1. Services that requested users to contribute photos or imagery for private sector consumption only (such as the Waze volunteer map initiative) were not included due to the uni-directional nature of these programs. Additionally, services that simply provided links to content offered in non-optimized formats (such as YouTube videos at TravelbyDrone) are also not included, as the reuse potential of these sources is minimal. Lastly, consulting companies or volunteer groups that do not broadly share their imagery or support the widespread gathering or integration from multiple sources (http://droneadventures.org/) are not included. The initiatives we focus on are those that support the collection of a broad range of imagery sources into one sharing platform, including the tools, services, and frameworks that serve this process. In total, 12 different organizations that support the collection and provision of user-contributed UAV imagery were identified (see Tables 2 and 3). We first categorize these organizations primarily based on role in the workflow presented in section 2 and use this classification of organizations to frame a discussion on the challenges associated with the development of an open user-contributed aerial image repository.

Table 1. Inclusion criteria and exclusion conditions for search results

Inclusion Criteria	Exclusion Conditions
• Offers hosting services for volunteer-contributed UAV imagery • Imagery data is available for free access of non-authoritative, volunteer-contributed • Project involves the use of volunteer-contributed UAV imagery for citizen science • Facilitates a sharing ecosystem for volunteered UAV imagery • Provides software tools or frameworks to support UAV imagery processing for users • Services provided in English language	• Does not facilitate free access to, and sharing of, UAV imagery • Only provides links to imagery in non-optimized formats for generating orthophotos or maps (i.e. YouTube links) • Project uses citizens to perform imagery analysis of UAV imagery, but the imagery is not volunteer-contributed

4. Results

The goal of this research is to create an initial classification of those organizations that contribute to the development of an open imagery repository, and establish the challenges to this development. Table 2 lists those organizations included in this research, classified by service type (i.e., the role that an organization plays, or product/service that they vend). Two main service types were defined; image hosting services (Table 2) and data processing tools (Table 3). These service types chart generally to the UAV mapping workflow steps of imagery stitching, imagery analysis, and map sharing described in section 2.

4.1 Image hosting services

Image hosting services are those that fill the role of map sharing (see section 2.4), providing a repository for UAV images to be stored and shared with other users. Of the four image hosting services studied, there are some notable differences in how they are setup to function. First, OpenAerialMap (OAM), built in part by the Humanitarian OSM team and inspired by the OSM project, provides the closest realization of an open user-contributed imagery repository, though currently the majority of imagery available for download from OAM is satellite imagery, with few contributions from sensors mounted to UAVs. Contributors can link imagery that they have uploaded to the Open Imagery Network (OIN), a licensing and metadata register that allows for mass cataloging and search of contributed imagery. Together OAM acts as the user-friendly front end for imagery search on the data catalog of OIN. This arrangement means there is no one entity responsible for hosting large amounts of contributed data.

Two other image hosting services were found, both variations on the same theme of a photo upload site. The first, dronestagram, provides a photo and video sharing site for drone enthusiasts to share imagery. Compared to OAM, there is no coordinated effort with dronestagram to link together imagery from different contributors, making this service more of a simple photo sharing site. The second example is The Nature Conservancy Coastal Resilience Project, which asks citizens to act as scientists, and report instances of coastal change impacts using smartphone or UAV imagery. Compared to dronestagram, this effort aims to link photos of a specific area and put these images to use in tracking coastal change over time. Because of this aggregation and sharing focus, the Coastal Resilience Project shows more similarity to OAM, but with a more specific geographic and thematic focus.

Table 2: Image hosting services/platforms

Name	Description	Business Model	Licensing
OpenAerialMap https://openaerialmap.org	Tools for searching, sharing, and using openly licensed satellite and UAV imagery. Built on top of the Open Imagery Network.	Free	Publicly licensed and made available through the Humanitarian OpenStreetMap Team's Beta OIN Node
Open Imagery Network https://github.com/openimagerynetwork	Framework and license for linking imagery.	Free	Creative Commons
Dronestagram http://www.dronestagr.am/	Photo sharing website focusing on aerial imagery.	Free, register account	Users own their own imagery. Imagery available for personal use only.
The Nature Conservancy Coastal Resilience Project http://coastalresilience.org/project-areas/california/el-nino-california/	Citizen science project using phones and drones to monitor the coastal impacts of El Nino	Scientific Research Project	Not specified

4.2 Data Processing Tools

The second main classification of organizations that provide services to the development of an open user-contributed aerial imagery repository are data processing tools. Mapping to the imagery stitching and imagery/map analysis (sections 2.2 and 2.3), these types of organizations provide the tools and frameworks for taking acquired imagery data from UAVs and turning it into value-added maps that provide information to end users. These organizations can be broadly separated into those that are open source and those that are commercial in their orientation. Three open source projects are included; OpenDroneMap, MapMill, and MapKnitter. Of these, OpenDroneMap is specifically designed for UAVs, providing a wide range of orthophoto, point cloud, and surface model construction tools with a command line interface. Comparably, MapMill and MapKnitter focus on image sorting, stitching and analysis for balloon or kite imagery taken with conventional digital cameras. Of these, MapKnitter aims to provide a more user-friendly interface to support the stitching process. These open source tools contrast with the expansive and fully-featured commercial options, such as Drone2Map, Pix4D, Maps Made Easy, DroneMapper, and DroneDeploy. These commercial options range from extensions building on full GIS platforms, to stand alone software, to cloud-based services available on a pay-per-use basis (Table 3).

This range of data processing options shows how commercial players have entered the UAV software market, providing both professional and enthusiast-focused options. These commercial players have a strong role to play in easing many of the technical challenges that the growing community of UAV enthusiasts will face, particularly if they have ambitions of contributing imagery or deriving any type of analysis from collected imagery. It is this 'middleware' role that these data processing tools fill in the UAV mapping workflow. They require the preliminary step of image acquisition to be complete, and depend on other mechanisms for effective sharing of maps.

Table 3. Image processing services and software

Name	**Description**	**Desktop or Web service & Actions Facilitated**	**Licensing & Payment Model**
OpenDroneMap http://opendronemap.github.io/odm	Open source toolkit for processing civilian drone imagery. The long-term aim of the tool is to optionally push resulting data to online repositories.	Desktop, Stitching	Licensing not specified; users assumed to own copyright. Free of charge
MapMill https://mapmill.org/	Public Lab tool for uploading and sorting balloon and kite imagery.	Web service, Sorting for subsequent stitching, Sharing	Creative Commons. Free of charge
MapKnitter https://mapknitter.org	Allows users to make maps from aerial photos.	Web service, Stitching	Creative Commons. Free of charge
Drone2Map for ArcGIS http://www.esri.com/products/drone2map	Convert raw still imagery from drones into 2D and 3D orthorectified products and perform some analysis.	Desktop, Stitching, analysis	Licensing not specified; users assumed to own copyright. Two payment requirements: 1. Paid ArcGIS Online License 2. Purchase additional Drone2Map software package (price not available).
Pix4D https://pix4d.com/	Software automatically converts imagery into georeferenced 2D maps and 3D models.	Desktop, Stitching, analysis	Users own their content. Four purchasing levels ranging from $350 USD for monthly rental to $8,700 for full purchase to own the software with 1 free upgrade and additional upgrades for $870/year.
Maps Made Easy http://www.mapsmadeeasy.com	Make orthophoto maps and 3D models.	Web Service, Stitching	Users own their content. Pay per use.

DroneMapper https://dronemapper.com/	Generate geo-referenced Orthomosaics and Digital Elevation Models.	Web Service, Stitching	Processing user imagery grants DroneMapper rights to the final product. Minimum charge of $250-$500 USD for opening an account.
DroneDeploy http://www.dronedeploy/com/	Cloud-based app for building aerial maps and models using drone imagery	Web Service, Stitching	Users own their content. Four types of subscription plans ranging from free limited use to $499/month for full suite of features.

5. Challenges to the development of a user-contributed aerial imagery repository

The characterization of existing image hosting services and data processing tools is an initial attempt to trace the current efforts around the development of a user-contributed aerial imagery repository. Given the still-emerging state of this type of initiative, it is valuable to draw from other, similar projects, for example, the OpenStreetMap (OSM) project, an open, user-contributed vector map of the world [62], [63]. OSM relies on a global community of contributors to create and edit geospatial content depicting largely built characteristics of the earth's surface (roads, buildings, and infrastructure). Since the founding of OSM in 2004, a significant amount of research on both the community of users [14], [64], data available via OSM [65]–[67], and the process and politics of its use [68] has been produced. This literature provides context for the development of a user-contributed imagery repository, outlining key concerns such as data quality [34], [56], [69], [70], licensing and reuse [62], [27]. These three areas are proposed as significant challenges to the development of an open imagery repository unfolds.

5.1 Data Quality

The issue of data quality has long been a significant consideration in cases of user-contributed datasets [31]–[34]. Comparisons between contributed information, such as OSM contributions, and authoritative data collected by official government mapping agencies, is mixed. In some cases, data is of comparable quality [63], [71], yet in others the quality is less than ideal [72]. Like the OSM-style contribution of vector data (points, lines, polygons), where data quality issues may be related to user-input issues, such as heads-up digitizing of satellite images, as well as technical issues, such as the accuracy of hand-held GPS units, a user-contributed repository of imagery must contend with UAV pilot skill in surveying a given area, as well as the technical limitations of the sensors. Given the incredible variety in terms of sensors on platforms, this can create a patchwork of images of varying quality that may not easily be integrated. For example, UAV users may be gathering imagery with a wide variety of sensors, from conventional point-and-shoot digital cameras mounted on balloons or kites, to purpose-specific high-end cameras with advanced stabilization mechanisms or specialty sensors, such as near-infra-red. This issue of data quality is both a technical issue and one that affects the ultimate utility of the data gathered. If data is of a low quality (resolution, high levels of distortion), this introduces additional challenges to stitching and sharing the imagery, as well as limitations of how the data can be used, and what level of information can be extracted.

5.2 Licensing and Data Reuse

Collaboratively-generated tools and projects, such as open-source software, rely on specific licenses to protect both the contributors and the users of a project. These licenses provide the critical 'terms of engagement' for who owns contributed data, how that data is to be shared, and what can be done with that data [73], [74]. For example, the provision of a specific license can determine whether imagery can be used for commercial purposes, or can restrict contribution from volunteers [73]. Additionally, as contribution of imagery could cross many jurisdictions, there are questions to ask about the transferability of user licenses across boundaries. Despite the importance of these issues, very little information is available on the licensing of imagery hosted and processed, except for some of the open source applications offer licensing under Creative Commons. The private organizations offer their services to paid clients, making it likely that the imagery input into the services by the clients is solely owned and accessed by those clients. Given this possibility, the ability of a user of these data processing services to then contribute an analyzed image to an open repository remains in question.

5.3 Broad Engagement of Contributors

As with many open, collaborative projects, generating a broad range of contributors is a challenge [75]. Despite increasing levels of UAV ownership in many areas, there is a significant step between owning and flying a recreational UAV for personal enjoyment and contributing collected imagery to an open repository. The technical skills and cost of software required for this are more demanding, requiring knowledge of specialized software for stitching together and processing images. This, along with the related cost for many of these data processing services, may make widespread contribution to an open repository simply impossible. Despite the requisite technical and computer knowledge required to operate a UAV, there may still exist a very real divide between the amateur or enthusiast and the professional operator. This challenge was encountered in the OSM community, where difficult-to-use software was seen as a major barrier that prevented new contributors from joining [76].

6. Conclusions

Our initial findings show that the development of an open user-generated repository of aerial imagery is underway. There are existing tools to help those interested in contributing to such a program manipulate imagery, and a handful of hosting services exist to bring together volunteered imagery. We present a characterization of organizations currently involved with the development of this type of initiative, defining them by type of service provided, whether imagery hosting or data processing. Despite this early progress on the development of an open user-generated repository of aerial imagery, there remains significant challenges. The challenges of data quality, licensing, and volunteer motivation have each been identified as obstacles or considerations. We provide these as directions for future work, where the principal actors in this area can contribute to the development of appropriate strategies to ease development. Coupled with the development of case studies where individual UAV owners contribute imagery for open use (whether in crisis situations as [1], or for other research, community, or commercial purposes), the implementation of such case studies will further define the opportunities, constraints and challenges to an open user-generated repository of aerial imagery.

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