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Merging Volunteered Geographic Information Systems

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This project discusses the history of both systems and how they have dealt with importing data in the past. It reviews what has worked well with previous imports and determines the best approach for merging volunteered datasets. It includes software that demonstrates the effectiveness of the proposed importation process.

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Introduction

User-generated content provides a valuable source of information and can provide information in areas where traditional information sources are not available. When user-generated content contains a spatial component, it is termed Volunteered Geographic Information (VGI) (Goodchild 2007).

Geographers have used a variety of methods to collect geographic information from untrained participants. Data collection techniques that are currently in use, such as Participatory GIS (PGIS), Public Participation GIS (PPGIS), and Community Integrated GIS, select specific participants to provide information. VGI takes a similar approach, but instead it allows the general public to volunteer their information.

VGI systems, prevalent on the Internet since 2005, include technologies such as Google Map Maker, Wikimapia, United States Geological Survey (USGS) National Map Corps, OpenStreetMap, and a mapping component of Flickr (Budhathoki 2010). These projects have different goals for collecting VGI and the users of these systems have different reasons for volunteering their geographic information.

The variety of VGI systems offers volunteers numerous ways to provide and to access information. A drawback of the variety of systems is that the systems are independent from each other. This means that if a volunteer would like to contribute to more than one VGI system, the volunteer is forced to reformat and reenter their information into each system. The USGS National Map Corps project and the OpenStreetMap project are examples of projects that offer volunteers the ability to volunteer their own information, but these projects currently do not have any procedures for data sharing between the two systems.

Geographers require a source of information to test their theories. Traditionally, this information has been obtained through fieldwork and by working with reliable secondary sources such as government and commercial entities. Funding for secondary sources is not always present and may be absent in many geographic areas (Goodchild 2009). While VGI can fill this role, it can also introduce new problems. Volunteers may be more comfortable with a group of tools in one existing mapping system, or users may be aware of legal issues surrounding data licensing, and have their own opinions of how they want their contributions to be used.

This project determines the technical and social issues involved with allowing information from a government system to be used in a private system. This includes working with data licensing, data transformation, and existing volunteer communities.

The research is conducted by working with user contributions from both the USGS National Map Corps project and OpenStreetMap. This includes literature about the USGS National Map Corps project and the documentation for OpenStreetMap. The OpenStreetMap community keeps track of its documentation through an online web application called a "wiki" which allows for a collaborative environment where all users can propose their own solutions to problems. This research uses the OpenStreetMap Wiki tool as well as it mailing lists as a way to determine best practices for importing new data into OpenStreetMap.

The intent of the National Map Corps is to allow volunteers to contribute data to the USGS that will be verified by a group of professional geographers and added to the public map upon verification. The USGS National Map Corps project provides an example of how VGI can be used successfully to meet the goals of an organization. An inherent problem with setting up an independent system is that the user contributions are not usually accessible with external tools.

The OpenStreetMap community has created software tools for managing changes to the OpenStreetMap dataset. This research determines how applicable these tools are to this project and the modifications that will need to be made in order to meet its goals.

Research question

What are the technical and social issues involved with allowing information to be transferred between United States Government volunteer mapping projects and the OpenStreetMap project?

Literature Review

Introduction

Online maps have been present since the early days of the World Wide Web (Hudson-Smith et al. 2009). There has been a sharp increase in the number of online map visualization tools since 2005. The increase has been spurred, in part, by services such as Google Maps, which allows web developers the opportunity to create online maps with little knowledge of the underlying geographic science (Haklay 2008). These new services collect much of their information from user-generated content.

User-generated geographic content has been termed Volunteered Geographic Information (VGI) by Michael Goodchild (Goodchild 2007). VGI has been able to capture a significant portion of online users, although it may also be viewed as “a flash in the cartographic pan” (Goodchild 2008). The field of VGI is still new and rapidly evolving and it has been recognized that there is merit for the gathering of local information that cannot be created remotely (Goodchild 2007).

The field of Geographic Information Systems (GIS) is not new to collecting information from volunteers. One common set of techniques is termed as Participatory GIS (PGIS), Public Participation GIS (PPGIS), and Community Integrated GIS (Dunn 2007), with the term PPGIS first being used in 1996 at meetings for the National Center for Geographic Information and Analysis (NCGIA). Corbett et al. state that PPGIS has roots in gathering of information about local communities in order to expose these communities to the outside world (Corbett et al. 2005). PGIS and PPGIS can also be viewed as the act of retrieving data related to political process (Tulloch 2008).

A dichotomy exists between professional geographers and technological geographers. The professional users who generate geographic content may not have formal training in geography, nor may they have any interest in geographic science (Flanagin et al. 2008). The technologist proponents of VGI are entrepreneurs that appear to have little interest in academia (Rana et al. 2009). This dichotomy is creating a debate over data quality and has been creating tensions between traditional, closed-source software providers, and free open source software enthusiasts (Crampton 2009). Goodchild notes that the line between professional and amateur is blurring, and that the GIS professional retains the tradition of high quality work (Goodchild 2009).

What is Volunteered Geographic Information?

Volunteered Geographic Information can be defined as any user-generated content with a spatial component. The volunteers are private citizens with few formal qualifications in geography, and their contributions are of variable quality. Overall the phenomenon represents an innovation that may have profound effects on GIS (Goodchild 2007).

VGI has emerged out of the more general concept user-generated content often termed as Web 2.0 (Crampton 2009). The term crowdsourcing has been used to describe the concept of gathering information from untrained volunteers. VGI can be described as a form of crowdsourcing where at least one component of the contributed information is geographic information. The geographic component can vary in size between contributions as small as a single point where an event took place to the precise outline of a continent (Tulloch 2008).

Neogeography

Another term related to VGI that has gained acceptance is neogeography. Hudson-Smith et al. define neogeography as a set of operations that work alongside professional geographers and do not conform to the protocols of professional geographers (Hudson-Smith et al. 2009). Neogeography is driven by web technologies and application programming interfaces (APIs) and allows users to share the locations of individual interests, such as the locations of personal photographs or places of interest discovered on a summer vacation (Turner 2006).

Neogeography has taken a controversial role in GIS, because it no longer requires the people making the maps to make decisions on projections, fonts, or symbolization. Goodchild argues that even in ESRI's ArcGIS, many of the features have an easy-to-use interface and default values, meaning that many users do not need to make these cartographic decisions (Goodchild 2009). The use of GPS and neogeography simplify some aspects of map creation to the level of general users. It is also possible that by using these tools, the users will become more interested in the geospatial information, and it will provide more of a need for trained GIS professionals (Crampton 2009).

Websites like Wikimapia and OpenStreetMap are classic examples of neogeography (Sui 2007). These websites use VGI in order to create a more complete map of the world. Wikimapia uses aerial imagery provided by Google to allow its users to orient the map when digitizing information. OpenStreetMap is designed to be an alternative to commercial and government street maps. OpenStreetMap allows users to add new information through an online interface or through external tools created by both volunteers as well as commercial entities.

Data mashups are a simple form of neogeography, and they have the ability to merge data from traditional sources with VGI (Lui et al. 2010). Data mashups can be created with a wide variety of tools, but the majority of these tools require the user to have an understanding of web technologies. Data mashups are much easier to create than a full application or website and can allow software developers and advanced users to present

VGI in a meaningful way.

Location Based Services

Another growing field of interest involving VGI is their use in location-based services (LBS). Jiang et al. discuss two definitions for LBS and explain that LBS can include any service that involves a spatial component along with a connection to the Internet through a mobile device (Jiang et al. 2006). LBS are aimed at mobile devices because these devices have the ability to move, can determine their location through a built-in Global Positioning System (GPS) receiver, and can access information using the Internet. LBS serve as a potential platform for users to create VGI. LBS can also act as a tool to allow non-technical users to aggregate and interact with VGI.

Public Participation and GIS

The practice of including the public in GIS has been called Participatory GIS, Public Participation GIS, or Community Integrated GIS (Dunn 2007). These terms are open to interpretation, and they serve more as a general idea than a specific concept. Dunn writes that Aberley, D. and Sieber, R. discussed fourteen guiding principles for PPGIS at the First International PPGIS Conference. These principles include: organization partnerships and implementations, the inclusion of under-represented groups, community development, and public access to official data (Dunn 2007).

Many innovations in GIS have come from fields outside of geography and outside of academia. This disconnect in the fields can cause there to be a lag between when these innovations are created and when they are incorporated into academic literature (Tulloch 2008). This lag is part of the reason that discrete definitions are slow to be created for technologies. Tulloch explains that the National Science Foundation (NSF) sponsored a workshop in 1998 on PPGIS in Santa Barbara, and by 2002 the papers and presentations about PPGIS had become so numerous that it warranted an annual conference specifically dedicated to PPGIS (Tulloch 2008).

Tulloch describes the four terms that have come to define PPGIS: Public, Participation, Empowerment, and Local Knowledge. The empowerment aspect is particularly important, as PPGIS is commonly described to have political motivations, with Sieber stating that the "ostensible goal of PPGIS is empowerment" (Dunn 2007; Sieber 2006).

Tulloch describes many different scenarios where PPGIS and VGI overlap. One argument for the distinction is that VGI may become more focused on applications and information gathering, where PGIS may become focused on the information collection process and outcomes of its research. Tulloch also notes that the fields are still emerging, and more literature on the subject is needed before a clear distinction can be made (Tulloch 2008).

Sui takes a different approach on the distinction as describes VGI as a subset of PPGIS. He makes the distinction that VGI is emerging as a concept, whereas PPGIS has established roots (Sui 2007). Tulloch and Sui both make clear that VGI and PPGIS are facing similar questions in their roles and applications. They both express concerns on impact on personal privacy that these techniques may pose (Sui 2007; Tulloch 2008).

Participants in PPGIS tend to be selected members of the public because of their political or professional affiliations, as is the case described by Nyerges et al. (Nyerges et al. 2006). This contrasts with VGI systems where contributors tend to be self-selected and contribute data based on their own personal motivations.

PPGIS appears to act as a survey method, while VGI appears to be closely related to personal interests and goals. VGI contributors appear to have more in common with volunteers participating in crowdsourcing projects. Tulloch suggests that a distinction between VGI and PPGIS will never be clear because many volunteers creating the data for their personal goals will also be interested in using their contributions in studies and in the political and policy decision process (Tulloch 2008).

Volunteer motivations

Volunteers have many different reasons for contributing geographic knowledge. Organisciak has outlined several motivational factors that lead volunteers to contribute data including: knowledge aggregation, idea exchange, and creation (Organisciak 2010). Other goals can be more entrepreneurial and can be related to the creation of data for future business applications (Rana et al. 2009). In some cases, volunteers are contributing data without their knowledge through their mobile devices. These contributions may have a negative connotation and are termed “incidentally volunteered data” and “geoslavery” (Tulloch 2008).

A case study of a popular online crowdsourced encyclopedia, Wikipedia, shows that for the major contributors, the contribution decreases exponentially from the user’s physical location (Hardy 2010). This case study demonstrates, in the case of Wikipedia, that users tend to contribute information to areas nearest to themselves.

VGI contributors tend to be on the forefront of the digital divide and have access to GPS and mapping technologies, including the World Wide Web (Goodchild 2007). Haklay explains that VGI coverage in rural and poorer areas is often lacking when compared to populous city centers and affluent neighborhoods. Haklay describes that locations with more complete data are considered “nice places” in which citizens have enough disposable income to obtain GPS-enabled equipment, the educational attainment to create such data, and the availability of leisure time. The lack of access to these technologies may increase the marginalization of already under-represented communities that are not able to provide such volunteered services (Haklay 2010).

Girres et al. confirms the same divide between affluent and deprived communities in a study of VGI contributions in France. The completeness of an area reflects the density of contributors much more than it reflects the density of information. Girres shows that areas with a young population are represented in more detail than most other areas of the study (Girres et al. 2010).

Data Quality in VGI

Information collected from untrained users is inherently prone to error. Many online neogeography tools incorporate a process in which volunteers can correct contributions created by other volunteers. Some websites, such as Wikimapia, require a certain amount of dedication to the site before a user if allowed to make a contribution. This can create an environment similar to that of Wikipedia, an online collaborative encyclopedia, where data accuracy can approach the accuracy of a commercial encyclopedia (Crampton 2009).

Flanagin examines the “credibility” of VGI and defines credibility as “the believability of a source or message” (Flanagin 2008). Information created by volunteers can be credible, and in some cases it can exceed the credibility of experts. This is especially true with local information and information based on individual opinion. Geographic information concerned with perceived information, such as neighborhood boundaries, can be far easier and cheaper to create using VGI than traditional survey methods (Flanagin 2008).

Flanagin also describes how traditional information sources became credible. He explains the long process of education, and reputation building. Credibility can easily be lost through a series of repeated errors, but it can also be gained through consistently high quality work. He also notes that this process creates information scarcity, so while the data may be of better quality, the data may also be lacking in many areas that may be useful (Flanagin 2008).

The studies by Haklay and Girres et al. show that VGI is often more complete in areas with a greater density volunteers. This can lead to large areas where information is completely lacking (Haklay 2010; Girres et al. 2010). The goals of volunteers may be very different than the goals of professionals and the resulting data often cannot be compared objectively (Rana et al. 2009).

The collection methods of VGI can introduce data quality issues; for instance, if the information source is aerial imagery on a cloudy day, cloud covered areas may not be mapped as well. This issue is also present for GPS units, which can vary in accuracy based on the local environment. Another issue is the spelling of words and naming of regions. Language, dialects, and misspellings can cause data not to come up properly in a search (Ricker

2009). These are common issues in VGI data quality assessments, but issues that can be hard to detect.

VGI may not be as authoritative as professional source information, but it can be useful when formal data is not available. Many applications such as emergency services require access to data quickly, and VGI is often unencumbered by licensing restrictions. VGI is not a replacement for official or authoritative data and it should not in used in scenarios where accuracy is critical.

Counter Mapping

Both PPGIS and VGI can be used to facilitate a practice called "Counter Mapping". Counter Mapping is the process of mapping an area against the local authority. It is a powerful way to allow marginalized groups to become recognized socially in an area where they are not politically powerful (Hodgson et al. 2002). Counter mapping techniques have been used in Tanzania, Nicaragua and Belize (Bryan et al. 2009), and Utah (Durrant 2001).

Counter mapping is particularly problematic when it comes to data quality, because of the animosities that may exist between the local users and the government. Counter mapping is designed to map the perception of the land by local users, but the users' perceptions can be corrupt, and users may see it as a chance to make themselves more prominent through ownership of resources. This was a particular problem in Tanzania as detailed by Hodgson et al., and is an issue that GIS professionals may not consider before implementing a project (Hodgson et al. 2002; Tulloch 2008).

Durrant writes about using counter mapping in the United States in an area where three agencies claim the rights to the same land (Durrant 2001). In this case, the land is mapped individually by each agency with each map representing the goals of the respective agency. In this scenario, there is less of a chance for deliberate corruption in the data and is an excellent use of the concept of counter mapping.

VGI and Privacy

When sharing location information, privacy can be of great concern. Curry argues that the right to privacy is changing, and the motivation for privacy today is different than it has been historically (Curry 1999). When volunteered information is aggregated, individual errors can be mitigated. VGI can be used in sufficient quantities to provide accurate trending information. This concept is often used in applications where the volunteers are unaware of their data contributions.

In Bath, England there was a controversial project to collect information from mobile telephones with Bluetooth to track the locations of individuals around the town (National Research Council 2010). Mobile phones have also been used in the United States to track users and provide traffic information (Behreandt 2007). These scenarios raise questions about privacy and ethics, but from an information science point of view, they can also be considered good sources of information.

VGI can be collected through automatic processes that require the user to set up the application only once. These applications can include locating friends, fleet management, emergency response, and monitoring patients (Jiang et al. 2006). When information is shared involuntarily, it can raise privacy issues and may present a need for location privacy in automatic location-based systems (Huang et al. 2010).

Mobile devices and LBS are of special concern when it comes to information privacy. It is very easy to track the locations of users by the locations of their mobile phones when their contributions are automatic. O'Sullivan states that the people working in GIS are struggling to come up with acceptable responses to the privacy issue and obfuscation and aggregation schemes can also result in lower quality information (O'Sullivan 2006).

Sui explains that crowdsourced information will either provide benefit for everyone or will push the already divergent groups of GIS farther apart (Sui 2007).

Applications of VGI

Traditional data sources are often controlled by commercial and governmental sources. These sources typically employ usage restrictions that may slow down the process of transferring the information to an interested party. In emergency situations, these time limitations may pose more of a threat than questionable data quality. Commercial and governmental sources are also dependent on funding, and typically only fund general projects, or projects to address a specific need.

One area in which VGI mapping is highly applicable is emergency services. VGI is not encumbered with the licensing and privacy restrictions that are imposed on governmental and commercial data, making it available for use with short notice. VGI not only has the ability to provide valuable information to emergency services, but also can help provide information to the public in a format that is easy to understand.

Traditionally, in disaster scenarios, residents have relied completely on the official agencies to provide them with information relating to the disaster. This has changed as residents are rapidly gaining access to technologies such as GPS and digital maps. Many of the agencies that are responsible for dealing with disasters do not have the funds or resources to share their information with the citizens. This creates a void that can be filled by VGI (Goodchild et al. 2010).

Goodchild et al. discuss how VGI has enhanced information availability in forest fire scenarios, especially where the severe conditions can spread faster than traditional methods of information dissemination. Disasters with longer durations can also benefit from VGI, with volunteers acting as an intermediary between the agencies and the general public (Goodchild et al. 2010). Traditional methods of printing maps and delivering them to the public has an inherent time lag that volunteers with digital devices are able to overcome and provide up-to-date information (Pultar et al. 2009).

VGI can be used as a sensor network with many applications. Goodchild distinguishes sensor networks into three types: Static sensors, Sensors carried by humans, and Humans themselves. By viewing humans themselves as mobile sensors, it is possible to theorize a network of over 6 billion sensors all capable of contributing information about a particular location. This concept can be applied to a large range of applications including: disease outbreaks (Chew 2010), wildlife population change (Goodchild 2007), food outlet availability (Mbugua et al. 2006), and tourism (Stewart et al. 2008).

In addition to information about a disaster itself, volunteers can also offer information about the areas affected by a disaster. In 2010 when a catastrophic earthquake hit the capital region of Haiti, very little existed in the way of traditionally sourced geographic information. This void was quickly filled by a flood of volunteers all over the world using aerial photography donated by the UN and commercial agencies (Organisciak 2010).

Volunteers quickly took to mapping the roads and buildings in the region using satellite imagery from the UN and commercial sources. Aid workers on location were able to update these base maps further in order to match the post-earthquake infrastructure (Organisciak 2010). This is one example of areas not well mapped by professionals. Similarly, many traditional mapping sources focus on legal boundaries and legal distinctions, but fail to provide a method for understanding the culture and social boundaries (Goodchild 2007).

There is merit in mapping how people perceive their landscapes as well as the legal definitions. Warf et al. describe neogeography as a whole as a conversation of the world as opposed to a mirror (Warf et al. 2010). For example, it is common to find roadways that are seasonally impassable marked as through roads on maps provided by traditional sources. In these cases it may be better to rely on local, untrained information than traditional information sources that may have overlooked this particular aspect.

The strengths of VGI are related to its uses. VGI is useful in situations where traditional data sources are not available. Where data sources are needed to be authoritative, such as legal information, volunteered data will never be as useful as traditional sources, where the creators are putting their reputations on the line. Some uses of VGI may cause ethical concerns, and these uses require more study before the community can accept them.

The Future of VGI

The future of VGI is tied to neogeography, crowdsourcing, and user-generated content and will need to be understood better before its relationship with GIS can be defined (Tulloch 2008). These technologies are constantly evolving and it is uncertain if they will be sustainable, or if they will be labeled as a “fad” (Sui, 2008). Tulloch suggests that the term “volunteer” may not truly encompass the contributors of VGI data, and that the terminology may need to be redefined if the field is going to continue to grow (Tulloch 2008).

Members of the public are well-suited for discovering data errors and providing information about change (Goodchild 2008). The future of VGI lies in applications where traditional products fail to meet the specific needs (Goodchild 2008). Traditionally a farmer needed to rely on soil and soil-moisture maps covering a large area to estimate the soil type on a particular farm. Farmers now have the ability to test soil and map soil locations themselves. If this information is shared with other local farmers, it can start to show trends in soil change that would not normally be studied by any larger group (Goodchild 2008).

There is a chance that neogeography will separate itself farther from traditional GIS as more casual users become familiar with the technology. The technologies also allow geographic information to be delivered to many more people than before, and may spark a renewed interest in the subject outside of academic and professional circles.

Foth et al. state that data visualization tools will increasingly become important methods to deliver information to policy makers and laymen. These tools can use VGI as their source while creating an interface that is accessible to the general public. Foth et al. also discuss the applications of using VGI in game development, and he cites simulator-style games as prime examples for VGI in games (Foth et al. 2009).

Evans-Cowley explores the use of mobile devices as they relate to VGI (Evans-Cowley 2010). Mobile devices contain built-in technologies for capturing photography, video, audio, and location information. LBS on mobile devices will continue to grow as more services are adopted, and as LBS gain more users, more VGI will be created. Mobile devices are location-based by nature, and will be both an excellent platform for non-technical users to access VGI and also for users to contribute their own information.

Literature Summation

VGI is user-provided information with a spatial component. It has been created out of the concepts of Web 2.0 and crowdsourcing. It is closely tied with neogeography which provides a venue for VGI as well as facilitates the creation of VGI. There has been some debate to whether VGI will be a long-lasting source of information of interest in it will wane over time and people will be looking for sources with more accountability.

PPGIS is a method of gathering spatial information from a collection of people with the purpose of generating social or political change. It can be used as a method for marginalized groups to put themselves on the map, and share their existence with the outside world. It can also be used to influence conservation efforts and show which methods have been effective.

PPGIS is different from VGI participation in that PPGIS is motivated by change, where VGI is motivated by individual factors. VGI participants can be further separated from PPGIS participants in that VGI participants are self-selected, whereas PPGIS participants tend to be recruited.

VGI data quality depends on the user and individual motivations. Flanagin provides an argument for credibility of volunteered information and explains that credibility depends on the subject (Flanagin 2008). VGI lacks accountability and liability; therefore, it cannot be used for legal or definitive matters (Sui, 2008). VGI also offers much more information than traditional sources, and it can be much more detailed. While the accountability is lower, the information can be credible when used in the proper context.

One of the larger issues with VGI is not its quality, but instead, its completeness. It has been shown that most VGI contributors are of a level of affluence that allows them to buy the proper equipment and spend the time creating the data. There are situations where volunteers have gone to underprivileged areas and provided tools and training in simple surveying techniques, but it can also be argued that these setups fall more in line with the concept of PPGIS.

Neogeography is constantly creating new ways to apply VGI. There are many cases where traditional geographic information sources do not cover the information needed for a particular application and creating the data can be prohibitively expensive. Traditional geographic sources do not often contain information about social uses of information.

There are many situations where VGI is not applicable. These cases have been used as a straw man argument to dissuade the use of VGI in situations where data can be purchased. Geographic information pertaining to legal or safety should not be sourced through volunteers that cannot be held accountable for the information. Volunteered information may also include bias and cannot be used to define an opinion.

VGI participation is a developing practice and the definitions and applications are in the process of being formalized. The similarities and differences between VGI and PPGIS are still being discussed and argued; consequently no consensus on their meaning currently exists. The future for VGI is very much tied to the web technologies such as Web 2.0, crowdsourcing, LBS, and neogeography. VGI has many applications that make it attractive to GIS users, but it also lacks accountability. VGI can never be an authoritative source of information, but it can be used in aggregation to study spatial patterns.

Research

OpenStreetMap is considered to be one of the most mature and successful examples of VGI (Sui et al. 2013). The success of OpenStreetMap comes from the community of OpenStreetMap users and the simplicity of the tools designed to allow these users to contribute to the map. United States government organizations, such as the United States Geological Survey (USGS) and the US National Park Service (NPS), have been inspired by OpenStreetMap to create their own online web map-editing platforms.

Both the USGS and the NPS have individual web map-editing projects that use OpenStreetMap tools as their core. As the OpenStreetMap project has matured, OpenStreetMap users have learned about and solved many data problems that are common in VGI systems. Organizations can use the OpenStreetMap tools to benefit from the work that the OpenStreetMap community has done in order to overcome these common problems.

The tools that are used in OpenStreetMap range from a core web application to many smaller programs that perform a single data-translation function. Projects that use the OpenStreetMap core gain access to these same smaller programs that have been used to make OpenStreetMap a success.

OpenStreetMap

OpenStreetMap was started in August of 2004 by Steven Coast, a research student at the University College London. Coast was looking for an alternative to the maps provided by the National Mapping Agency in the United Kingdom which were subject to strict copyright. Coast used a consumer-grade GPS to draw London streets on a map and shared his work with his colleagues at University College London. The project caught on and eventually grew into OpenStreetMap.

One of the strategies that OpenStreetMap uses to attract new contributors is the organization of social events where attendees are asked to contribute to OpenStreetMap. An early event in the history of OpenStreetMap was the Isle of Wight workshop, which showed that a small team of volunteers could map a substantial area in a short time. The success of this event led to a similar event in Manchester, UK (OpenStreetMap 2014d). Mapping parties are still organized across the world today, but are only one of the methods used to attract new contributors.

The OpenStreetMap foundation is a not-for-profit company based in the United Kingdom that acts as the owner of the OpenStreetMap project. (OpenStreetMap 2014b) The OpenStreetMap foundation supports working groups that are dedicated to dealing with specific parts of the OpenStreetMap infrastructure.

OpenStreetMap was built on volunteer contributions created with GPS units to avoid copyright issues. Many organizations, such as the United States Government, do not retain any copyright to their works, making their works free for anyone to use. Datasets created without copyright restrictions can be brought into the OpenStreetMap by import. Some of the larger data imports include: street information in the United States from the United State Census Topologically Integrated Geography Encoding and Referencing (TIGER) project in 2007 (OpenStreetMap 2014h) and point information from the USGS Geographic Names Information System (GNIS) in 2009 (OpenStreetMap 2014f). These imports allowed OpenStreetMap to have more complete coverage in some areas, but imports can also have a negative effect by overwriting existing work surveyed by contributors.

The USGS GNIS import was designed to be a two-way connection between the USGS GNIS system and OpenStreetMap. The two-way connection was maintained by preserving a primary key between the USGS GNIS database and the OpenStreetMap database. An initial import was done in 2009, but there has not been an effort to update these contributions since the initial import.

United State Geological Survey

The USGS began collecting geographic information from volunteers in 1994 through a program called the Earth Science Corps. The project consisted of USGS employees sending paper maps to volunteers around the country and having the papers mailed back with updated annotations. This process moved to the Internet in 2001 and began using GPS technology. In 2008 the project was suspended due to limited funding (United States Geological Survey 2014b).

The USGS launched the OpenStreetMap Collaborative Prototype (OSMCP) in 2010 as a tool for internal use within the USGS. The OSMCP was created to determine if the OpenStreetMap infrastructure could be used to meet the goals of the USGS and its partners. The OSMCP project focused on 30 data types found in the Nation Structures Dataset (NSD), which combines data from various authoritative sources including the Geographic Names Information System (GNIS). The scope was limited to parts of the state of Kansas (Phase I), and the Greater Denver Metropolitan Area (Phase II). The project involved a mapping component as well as a quality control component in order to ensure that the information that was contributed was correct (Poore et al. 2012).

The second phase of the project was opened to students at the University of Denver and the University of Colorado Denver. The second phase allowed students to contribute to the map and perform quality controls on other students' work. The project was successful and a pilot project was opened to the public in the state of Colorado. The project was opened to the public in all 50 states in mid-2013 (Poore et al. 2012).

The public project focuses on 10 data types:

- Schools
- Universities
- Fire Stations
- Police Stations
- Hospitals
- Correctional Facilities
- State Capitols
- Post Offices
- Cemeteries

The USGS National Map Corps project is designed to update information in the NSD. The contributions in the National Map Corps system are also added into another USGS project called the National Map, which serves as an online data repository for much of the geospatial information collected by the USGS. The contributions will also appear on printed topographic maps made by the USGS.

The National Map Corps project is designed around a data validation process:

1. A volunteer makes a contribution.

2. The contribution is verified by other volunteers who have a certain amount of contributions to the map. (Currently 25)

3. The USGS runs a final quality check on the contribution and approves it for inclusion in the NSD.

The National Map Corps project was built using customized versions of the software used to run OpenStreetMap. The National Map Corps uses a modified server architecture called the Rails Port, and an editor called Potlatch that is based in Adobe Flash. The project also makes extensive use of a tool called Osmosis that performs data processing tasks and allows for analysis by USGS employees (United States Geological Survey 2014a).

The USGS National Map Corps project demonstrates that the OpenStreetMap platform can work for other projects. The National Map Corps project also serves as an example of a problem with current VGI systems, it is easy to contribute to these systems, but it is often difficult to extract user contributions.

National Park Service

The National Park Service (NPS) manages over 400 park units in the United States. Many small park units do not have the resources to create their own maps. The NPS aims to allow non-technical volunteers to contribute geographic information to these parks with a project called "Places".

The Places project is built using tools similar to the OpenStreetMap project, but customized to meet the specific needs of the NPS. The Places project is another example of a project based on OpenStreetMap that is currently a closed system. As of this writing, the Places system does not have an established validation process and the project is not yet in a state to be exported into OpenStreetMap.

Software Review

OpenStreetMap is designed to be an open community for more than just volunteers interested in contributing geographic information. OpenStreetMap provides full documentation of its source code, data flows, and application programming interfaces in order to promote participation from the software development community. This well-supported community has created many tools that are useful for importing and exporting data from OpenStreetMap.

The core of OpenStreetMap is a database running on open source database software called PostgreSQL. The OpenStreetMap website uses a database schema for PostgreSQL called apidb. The apidb schema is designed to keep track of the current status of the OpenStreetMap dataset as well as to maintain a complete history of all changes that have been made to the map.

The OpenStreetMap community has created a tool called Osmosis that is designed to perform data management tasks on the OpenStreetMap database. These tasks include: extracting data within a selected geographic area, comparing two datasets and determining the differences, and transforming the data into other database schemas.

The OpenStreetMap community has created a few different database schemas for different uses within the project (OpenStreetMap 2014c). The Osmosis tool can create a database schema known as pg_snapshot. This database schema stores the OpenStreetMap data in a spatially enabled database system built on the PostgreSQL data system called PostGIS. The pg_snapshot schema uses a spatially enabled database and is a suitable platform for performing spatial analysis.

The OpenStreetMap community has created tools that make it easy to add volunteered data into OpenStreetMap. These tools include an easy-to-use, yet powerful, web interface called iD, and a desktop application called JOSM designed for more advanced editing. The community developed a plug-in for JOSM for conflation that provides an advanced user with a user interface and the proper tools to merge data from an outside dataset into OpenStreetMap. This plug-in is capable of giving an advanced user the ability to merge a dataset like the USGS National Map Corps project into

OpenStreetMap, and the process is given as a possible use on the webpage for the plug-in (OpenStreetMap 2014e).

JOSM is an excellent tool for performing spatial tasks on OpenStreetMap data, but many data import projects are too big to be performed by one person acting alone. A tool called MapRoulette provides a simple web-based interface for users to fix more advanced data integrity issues, such as topology errors, one fix at a time. MapRoulette has been proved to be an effective method or performing large tasks, with over 70,000 errors corrected in a span of less than three months (van Exel 2014). The MapRoulette tool interface is seeded with possible errors detected through scripts run on OpenStreetMap data. The error list is divided into individual tasks that users can perform, so that many users can work on fixing a single larger problem.

Another web-based project called OSMLY was built for the city of Los Angeles as a tool for merging the city's parks into OpenStreetMap. OSMLY uses the same approach as MapRoulette by using volunteers to validate changes individually before they are added to the OpenStreetMap database. OSMLY represents an excellent workflow that can easily be modified to work with data from the United States Government. OSMLY currently does not support point data, so it is not directly applicable to this project's goal (Lidman 2014).

Design and Implementation

The USGS National Map Corps project allows volunteers to make updates to information using a web interface. Much of the information that the volunteers are collecting can be useful in OpenStreetMap. Volunteers for OpenStreetMap have imported an older version of the database used in the National Map Corps as a method to seed the OpenStreetMap project. The updated USGS information in the National Map Corps project has been verified by geospatial professionals, and represents a valuable import into the OpenStreetMap project.

There are challenges with importing information into OpenStreetMap presented by the community. The community discourages data imports and enforces a license that is not compatible with the public domain requirement from the USGS.

One approach to merging data from the USGS into OpenStreetMap is to use a tool like JOSM that can perform the task of merging data from one project into another, but it is a time-consuming process and relies on the effort of a single motivated contributor.

Another method to add the contributions from the USGS National Map Corps system to OpenStreetMap is to create a system that allows many users to review each change and verify which contribution is correct. This is the approach that tools like MapRoulette and OSMLY use for their specific tasks. These tools provide valuable information on how dividing tasks into small units that can be performed by many individuals can help fix advanced data issues.

It is not technically challenging to import data directly to OpenStreetMap and the process has been documented well. The more difficult issue is making these changes while keeping the volunteer community engaged in the process.

Software Design

Tools like MapRoulette and OSMLY show that volunteers can solve advanced geospatial problems when they are broken up into smaller problems and clearly explained to the users. This project uses their success as a guide for its software design. This project uses the methods proven by MapRoulette and OSMLY to allow volunteers to manually update OpenStreetMap. This project also uses a simple user interface designed to make merging easy for non-technical users.

This project is built by using existing open source software where possible in order to reduce overall development time and to build from the success of other projects.

The user interface for this project is a web-based JavaScript mapping library called Leaflet. Vladimir Agafonkin and a team of contributors developed Leaflet in 2007 as an alternative to larger mapping libraries. (Leaflet 2014) A plug-in is available for Leaflet called "Leaflet Draw" which gives developers the ability to add a control to their maps where the users can move points, lines, and polygons on the map and save them back to a server. The Leaflet draw plug-in is used to allow volunteers to move a point to the correct location (GitHub 2014).

OpenStreetMap has an agreement with Microsoft Bing Maps to use their aerial imagery as a resource when digitizing information into OpenStreetMap (Fairhurst 2014). The USGS does not have agreements with any commercial data providers and uses public domain imagery from the National Agricultural Imagery Program (NAIP). Data digitized using Bing imagery is only licensed to be used in the OpenStreetMap project. Both Microsoft Bing and NAIP imagery sources are available to the volunteers using this project; the imagery type used for their contribution is stored in the database in order to keep track of issues with data licensing.

The backend for this project is a server running the PostgreSQL database system with an extension called PostGIS installed on it in order to allow spatial queries to be performed. The PostgreSQL database is loaded with a database schema from designed by OpenStreetMap developers named the pg_snapshot schema. The database also includes custom table to tracks user contributions in order to provide a complete history of what points have already been updated in OpenStreetMap through this tool.

The initial project only matches USGS and OpenStreetMap contributions in the state of Colorado. This project will be able to focus on metrics and proof of concept by limiting the contributions to a small area. The state of Colorado was used for the initial launch of the USGS National Map Corps project and has the most complete dataset. This project will keep track of the effectiveness during the initial phase and improvements will be made before the project is opened to the entire United States.

The contributions from the USGS and OpenStreetMap are processed and matched using the GNIS id field to determine which points are likely to referrer to the same object in both systems. If more than one point is a candidate for matching, the points are ranked in order of distance from the point in the USGS database.

```sql
SELECT
  nodes.id as usgs_id,
  nodes.version as usgs_version,
  nodes.tstamp as usgs_tstamp,
  nodes.tags as usgs_tags,
  nodes.geom as usgs_geom,
  osm_nodes.id as osm_id,
  osm_nodes.version as osm_version,
  osm_nodes.tstamp as osm_tstamp,
  osm_nodes.tags as osm_tags,
  osm_nodes.geom as osm_geom,
  ST_Distance(nodes.geom::geography, osm_nodes.geom::geography) AS
distance
FROM
  nodes JOIN osm_nodes
  ON
    nodes.tags->'GAZ_ID' = osm_nodes.tags->'gnis:feature_id'
WHERE nodes.tags->'Validated'='1';
```

Figure 1

Interface

The user interface first provides the user with the information from a point in the USGS database with a probable match in OpenStreetMap. The user is instructed to verify that both the USGS and OpenStreetMap data points are referring to the same physical object.

If the user answers yes, the user will then be asked to verify the attributes associated with the point. Once these are approved, the user will be required to move the point to the location that he or she believes is correct. The new point is stored in the database.

After three people place the point within ten meters of each other, the center of the three contributions is added to OpenStreetMap along with any information unique to the USGS National Map Corps project that has been approved by the users. The center of the contributions is determined by using the PostGIS command ST_Centroid on the selected user contributions.

If the user answers that the point cannot be matched to any point in the OpenStreetMap database, it will be logged. After three people decide that the point does not match any point in the OpenStreetMap database, it will be removed from the list of points that are possible candidates for matching. This list can be used for future projects and can allow new points to be added to OpenStreetMap from the USGS National Map Corps dataset.

Once the user completes the task for a point, the user can continue matching other points through the interface. When the user presses the continue button, another possible match will be presented and the process will continue as long as the user wants to continue mapping and there are points to be matched.

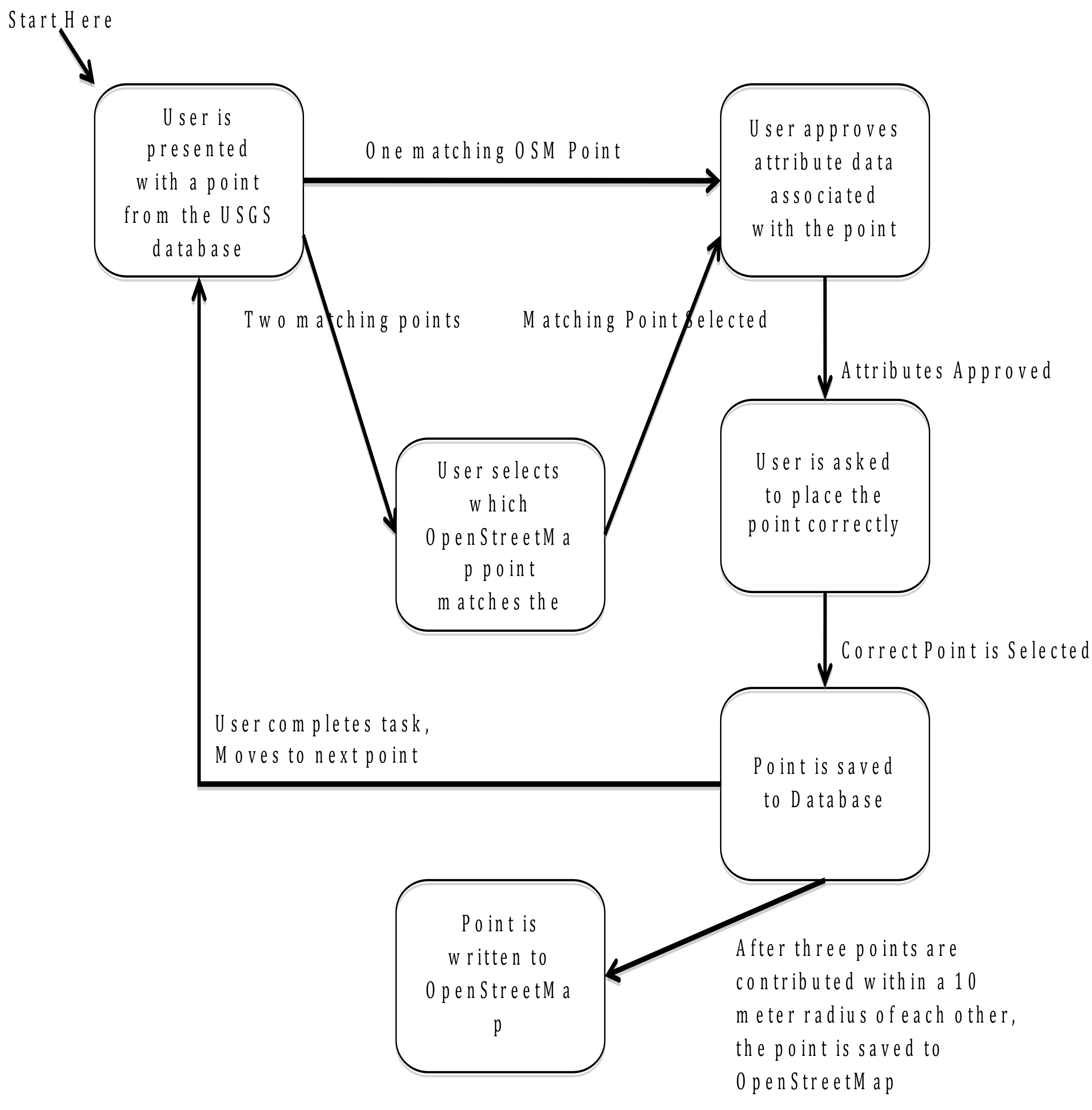

Figure 2

Discussion

Volunteered geographic information systems use a community of volunteers to add information to their maps. Data imports from traditional and authoritative datasets may improve quality, but also may negatively affect the communities that keep these systems alive. This project aims to use the communities to help improve data quality while keeping the community engaged with the updates. The effectiveness will be monitored so that improvements can be made and this project can be used to merge more information sources into the OpenStreetMap project.

Why Use Volunteer Effort?

The validated contributions in the USGS National Map Corps database are similar to traditional GIS data because professionals have verified the points individually. Since the GNIS dataset was imported to OpenStreetMap, volunteers have made changes to some of the points and the points may contain information that the National Map Corps did not collect. While the data in the National Map Corps system may be more authoritative, the contributions to OpenStreetMap may contain local geographic information that a professional surveyor may not have added.

The contributions to OpenStreetMap since the GNIS dataset was originally imported may be valuable enough that overwriting them with more authoritative data may represent a loss of valuable information. There is also a social component involved in which users may become discouraged if there is a chance that a large group may overwrite their contributions. It is important to the OpenStreetMap project that community stays involved and takes pride in their contributions.

This project uses volunteer efforts to perform data merging tasks because each point is different and it would be unfair to OpenStreetMap contributors to overwrite their contributions without reviewing each point. This process combines the technical conflation tools with a social component in order to promote the OpenStreetMap community while providing the database with contributions from an authoritative data source.

Effectiveness

The MapRoulette tool has demonstrated that it can collect over 50,000 contributions in a time span of less than three months. If this project can emulate at least some of the effectiveness of the MapRoulette project, it can complete the over 2000 possible matches between USGS and OpenStreetMap datasets within Colorado in a matter of days.

The MapRoulette project demonstrates that bulk changes can be made through aggregation of volunteer contributions without negatively affecting the OpenStreetMap community. The MapRoulette project also provides a technical solution for editing OpenStreetMap that meets the technical goals of the OpenStreetMap project.

This project implements the data aggregation approach taken by projects like the USGS National Map Corps and Wikimedia where multiple contributions are required before contributions are counted as valid. This process may reduce the number of contributions over time, but it will increase the reliability and validity while reducing problems with vandalism.

This approach solves the project goal of merging information from the USGS National Map Corps project into OpenStreetMap. The project aims to provide a method for other authoritative sources to contribute their information while addressing both technical and social issues with the OpenStreetMap community. The National Park Service Places project is not currently in a stage of development in which it can be exported to OpenStreetMap. Future studies can address the individual issues involved with importing contributions from the National Park Service and other sources.

Future Study

This project can be applied to any dataset that is compatible with the OpenStreetMap license. This project only addresses the issues involved with the USGS National Map Corps project, but it can be extended to work with other projects. This project has not yet been thoroughly tested and issues, both technical and social, will be monitored and fixed to ensure the overall effectiveness of this project.

Future studies can also address what changes need to be made to other datasets to allow the use of this method of merging information into

OpenStreetMap. The National Park Service will have a dataset available in the next year that can use this process, and the process can be extended to other federal government agencies and local government agencies.

Conclusion

Volunteered geographic information represents an innovation that may have profound effects on GIS (Goodchild 2007). OpenStreetMap is one of the successful examples of VGI and demonstrates its usefulness and effectiveness (Sui et al. 2013). Organizations, such as the United States Geological Survey and the National Park Service, have observed the success of the OpenStreetMap project and have created their own VGI projects. These projects act independently of each other and contributions to one system will not make it into another system. Contributions from one system cannot be imported into another system without the possibility of overwriting existing information. Automated contributions to the OpenStreetMap project may also have social implications because these contributions may discourage individuals from contributing if there is a chance that their contributions will be overwritten without review.

Manual data conflation is required in order to ensure that information from authoritative data sources can be combined with OpenStreetMap information without creating new problems with the OpenStreetMap community. Projects like MapRoulette and OSMLY have proven the effectiveness of this approach, and this project aims to use these proven techniques for the process of data conflation.

The effectiveness of this project will be monitored, and the project will continue to improve and to expand its reach. This project can be used to attract new users to VGI projects like the USGS National Map Corps because the users will be able to make their contributions once and have their contribution propagate to multiple systems. This project will solve the fragmentation issues involved with creating separate volunteered geographic information systems and will allow these systems to work together to create a more complete map of the world.

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Appendix

This project allows users to match points from the United States Geological Survey's National Map Corps project with points in OpenStreetMap. The interface is designed to guide the user through the steps to reduce the chances for any mistakes. The process is:

1. The user loads the main web page and begins to use the merge tool. (Figure A1)
2. The user selects the "Begin" button and is prompted with two points to verify a match. (Figure A2)
3. The user is asked to decide which tags can be added or removed from the OpenStreetMap database. (Figures A3 and A4)
4. The user is asked to place the point closest to where it belongs. (Figure A5)
5. After three users verify the point, the point can be added into OpenStreetMap. (Figures A6, A7)
6. If the user decides to contribute the point to OpenStreetMap, a login screen will appear. (Figure A8) If the user does not want to contribute, the point is logged and another user can add the point to OpenStreetMap.

7. If the point is added onto OpenStreetMap, the user will be prompted with a message. (Figure A9)
8. The process will continue until all points have been matched.

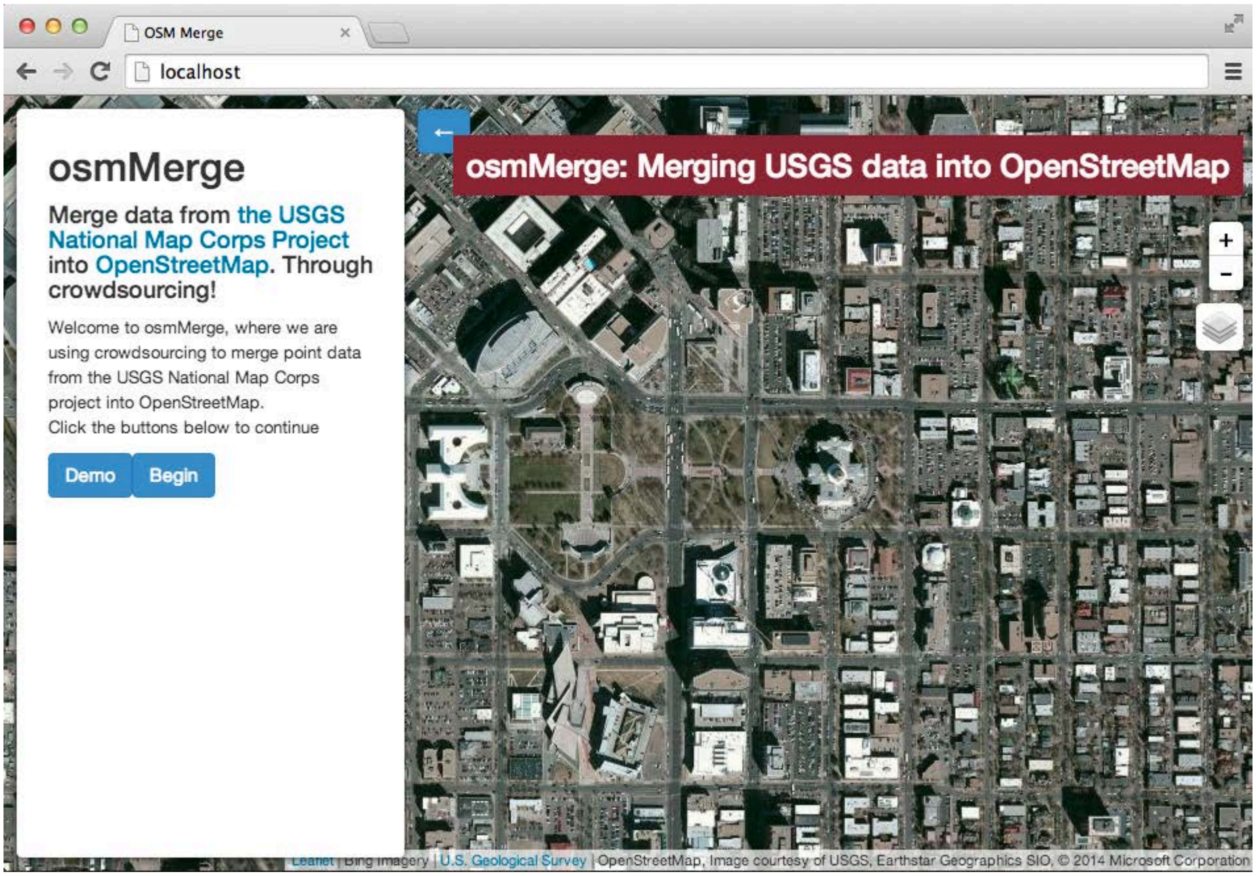

Figure A1: Introduction Screen

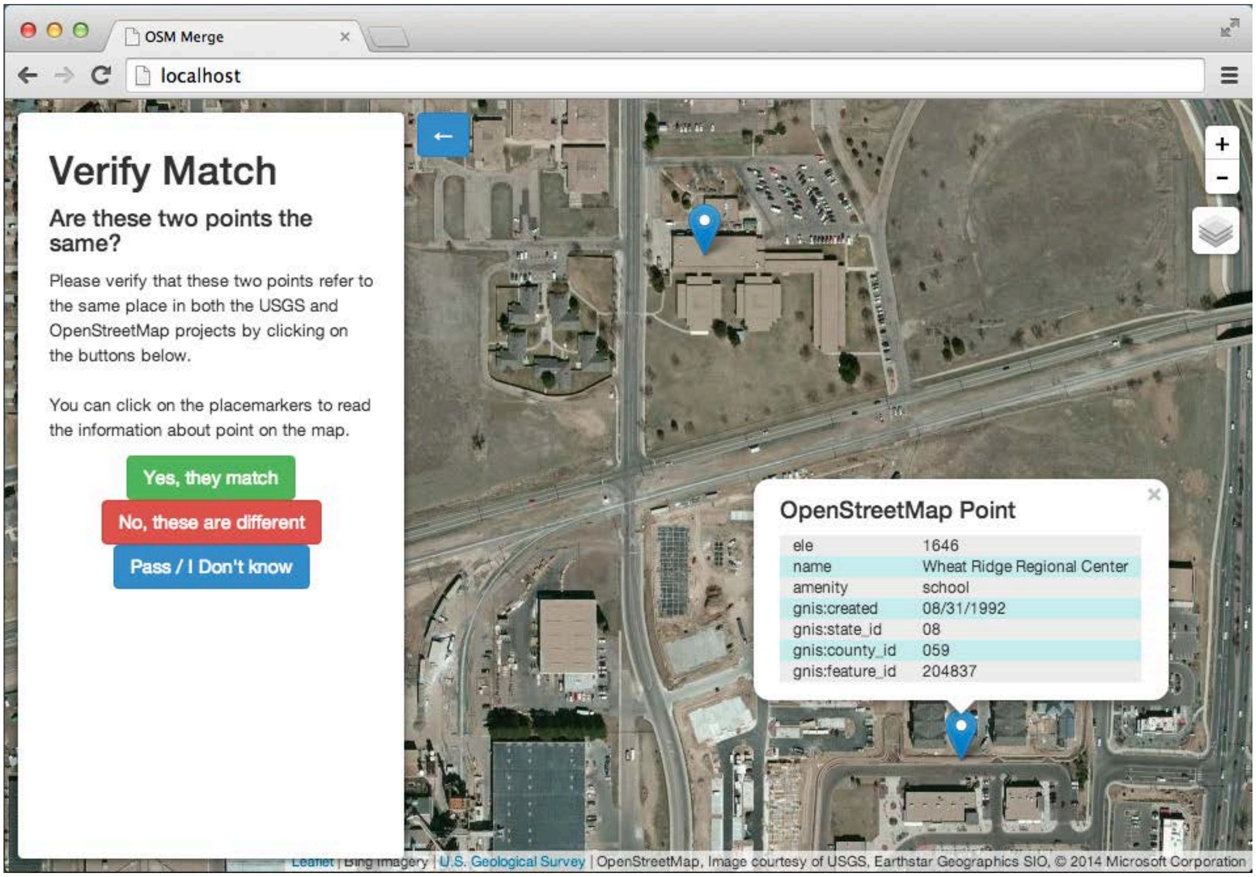

Figure A2: Verify Match Screen

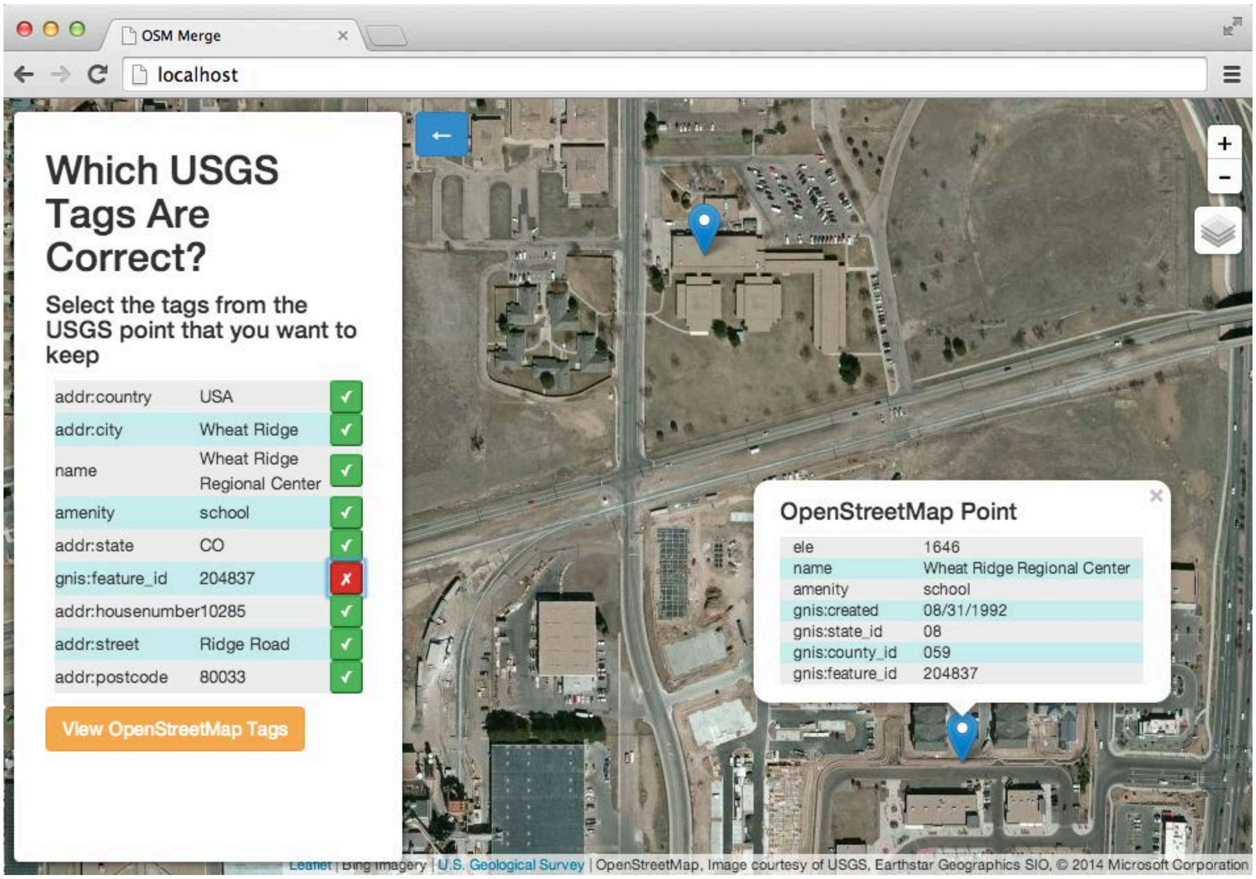

Figure A3: Tag verification screen

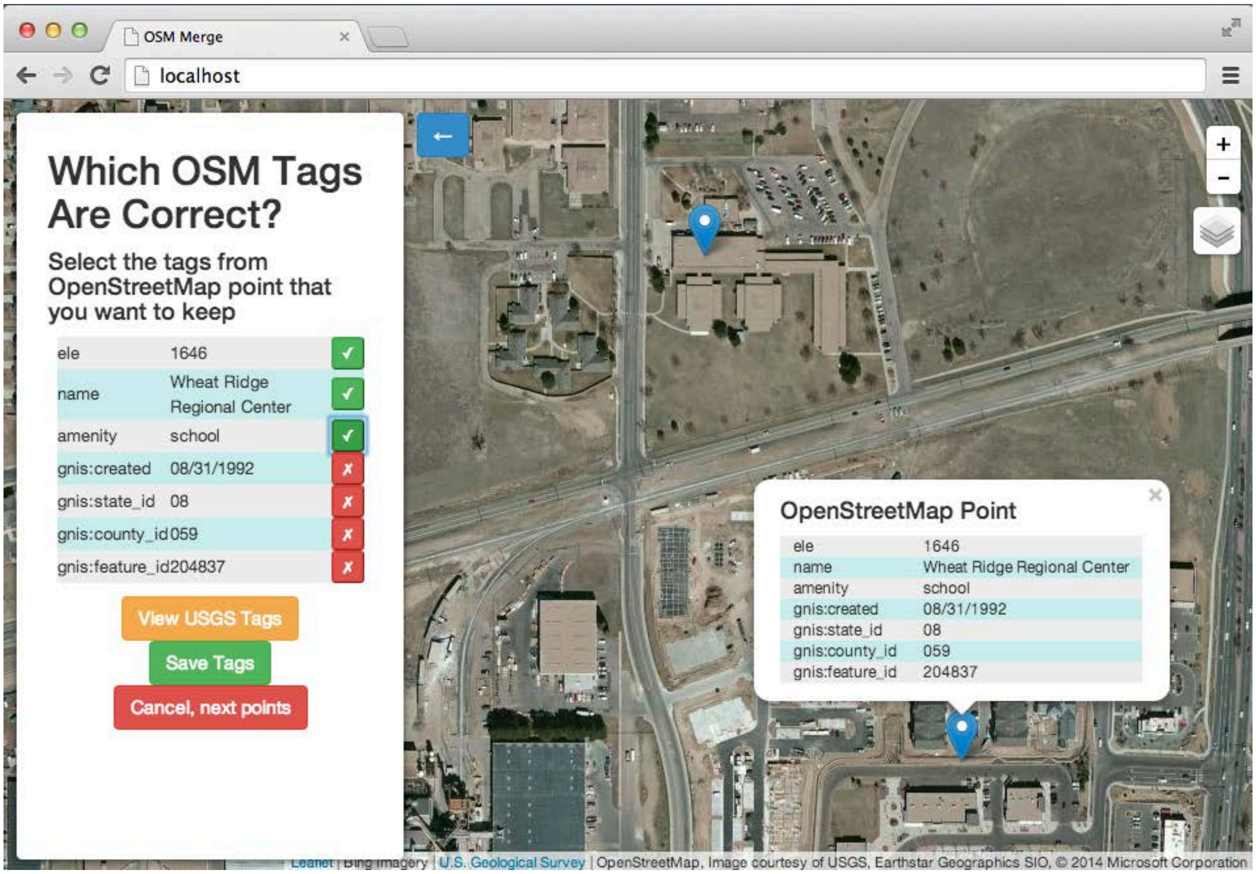

Figure A4: Tag Verification Screen #2

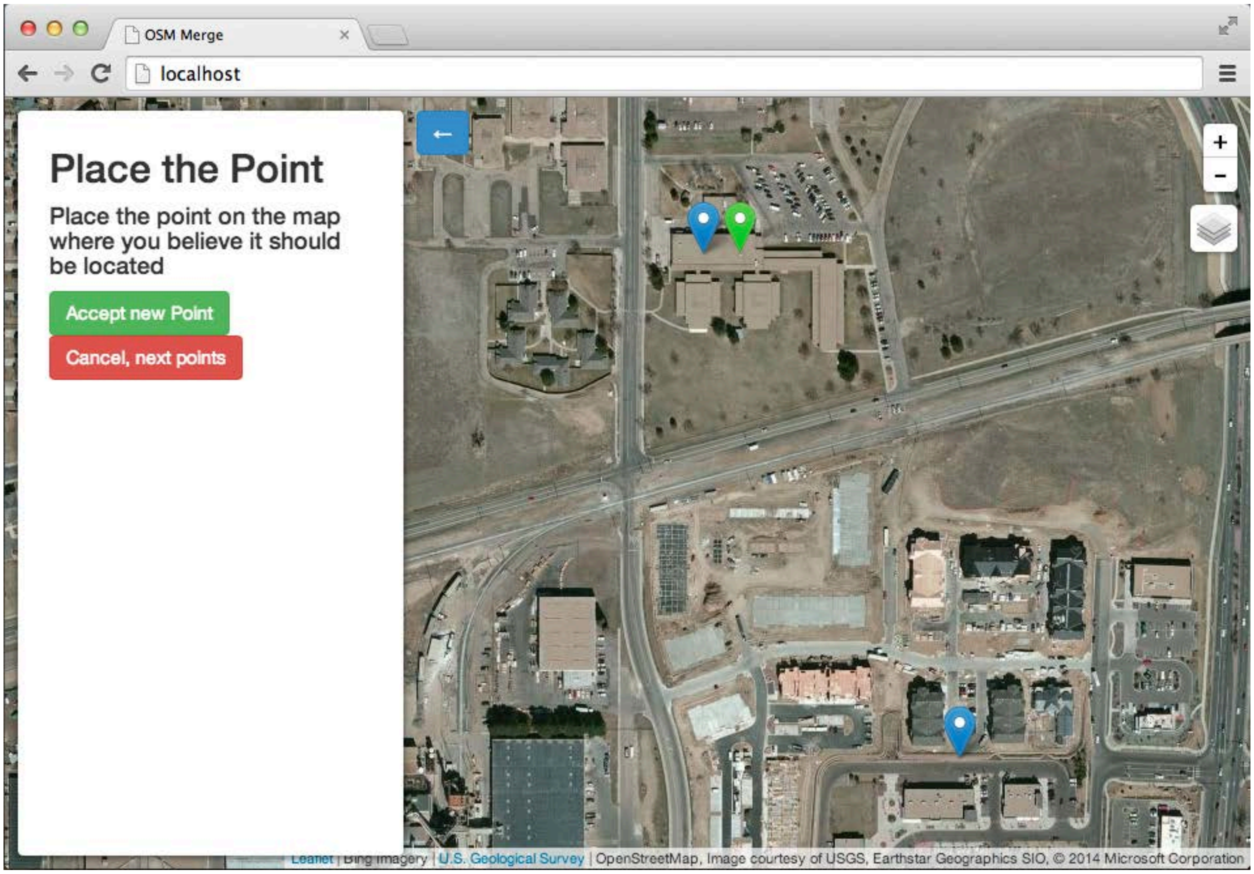

Figure A5: Add point to the map

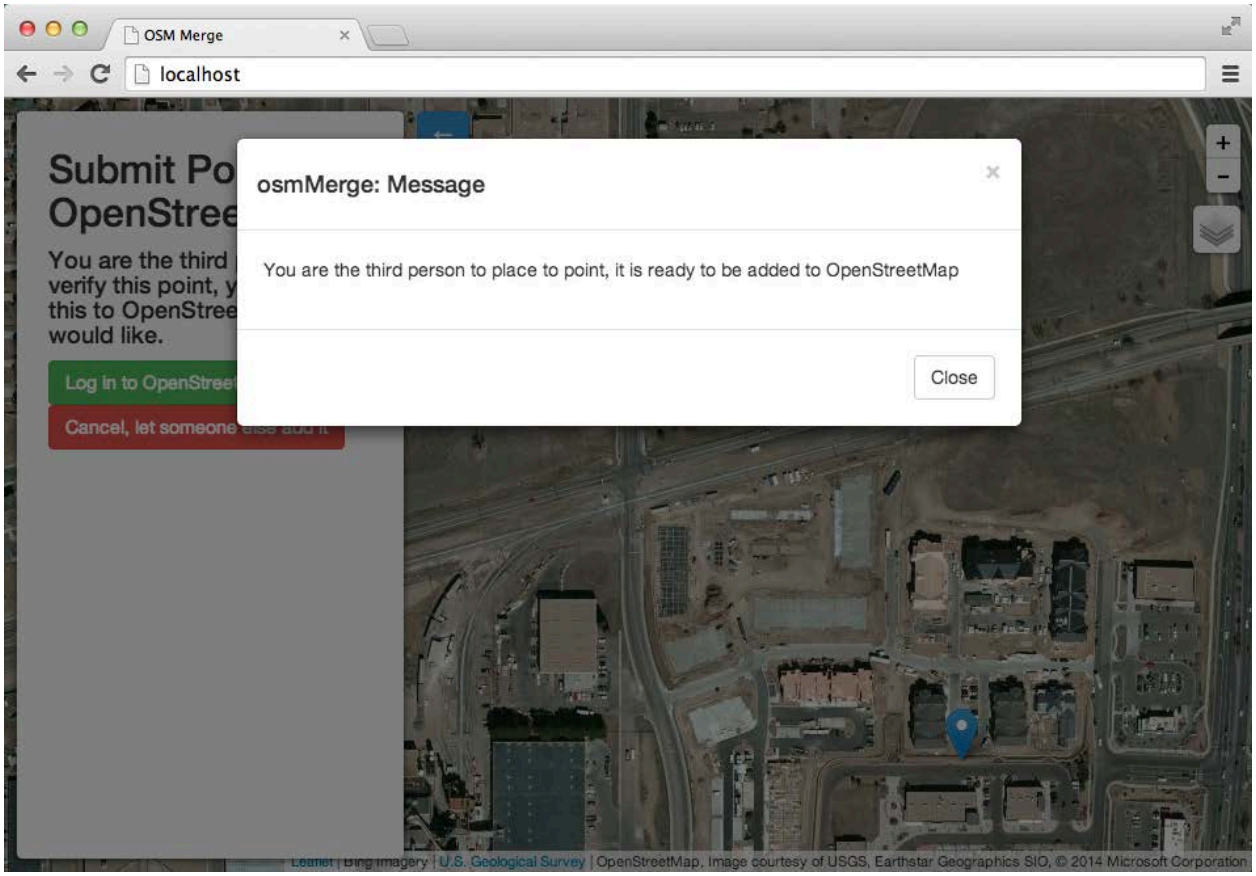

Figure A6: Add point to OpenStreetMap Message

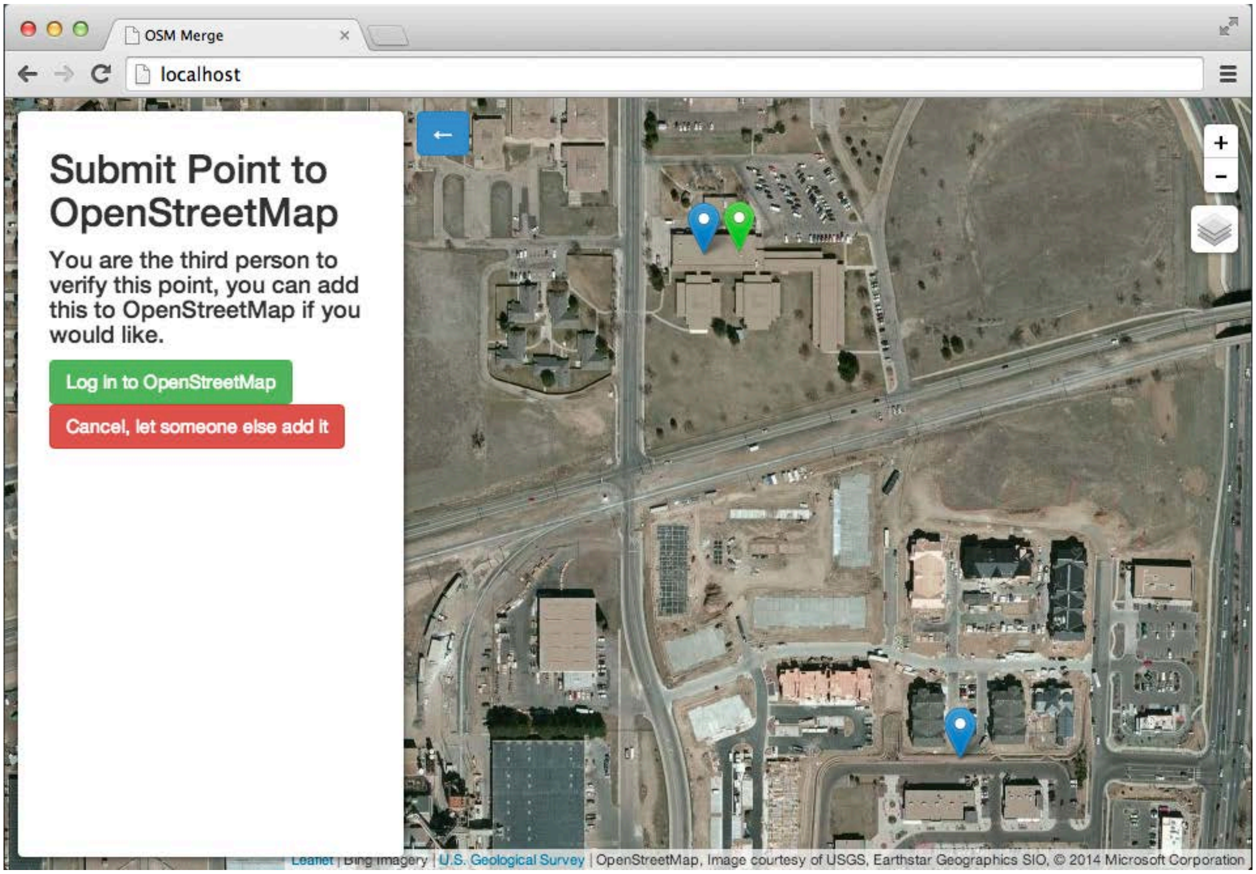

Figure A7: Submit Point to OpenStreetMap

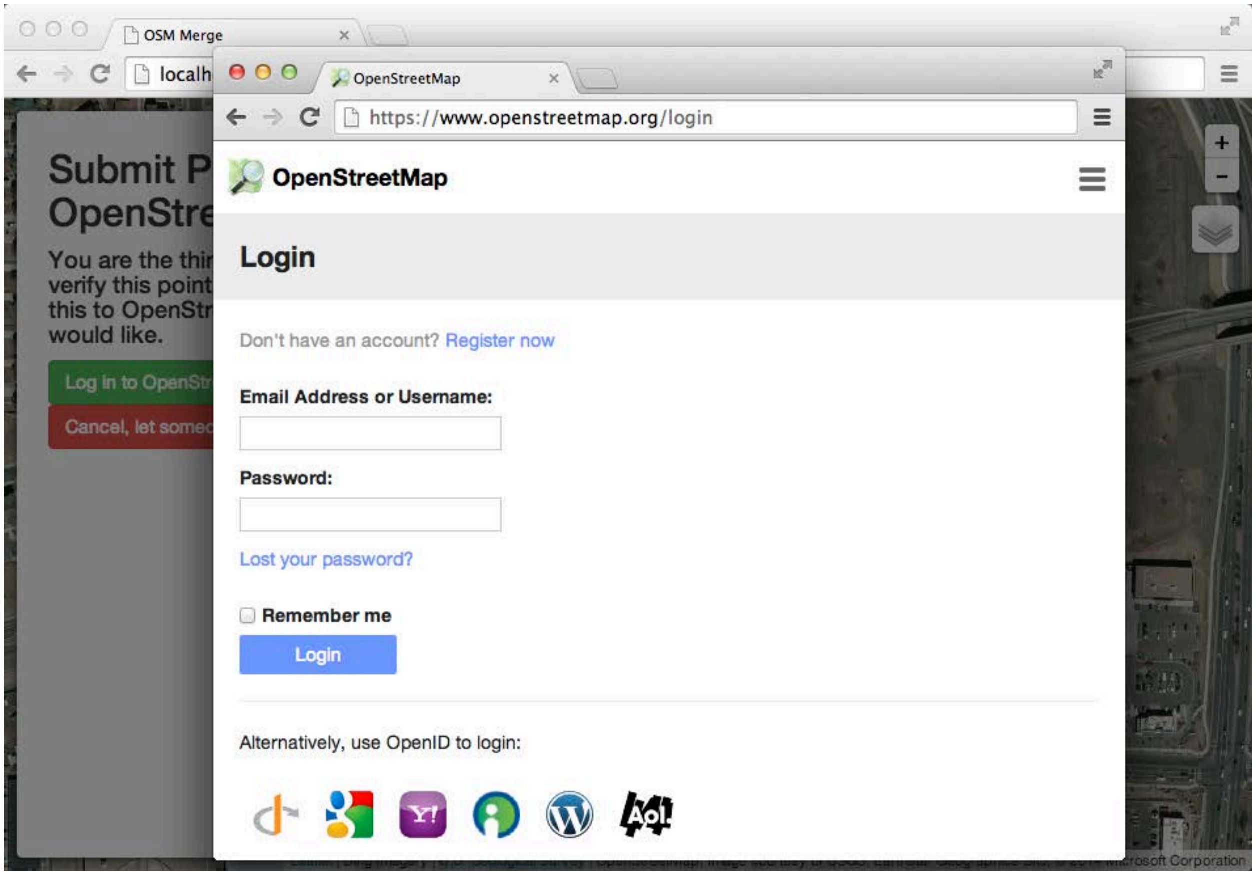

Figure A8: Login to OpenStreetMap

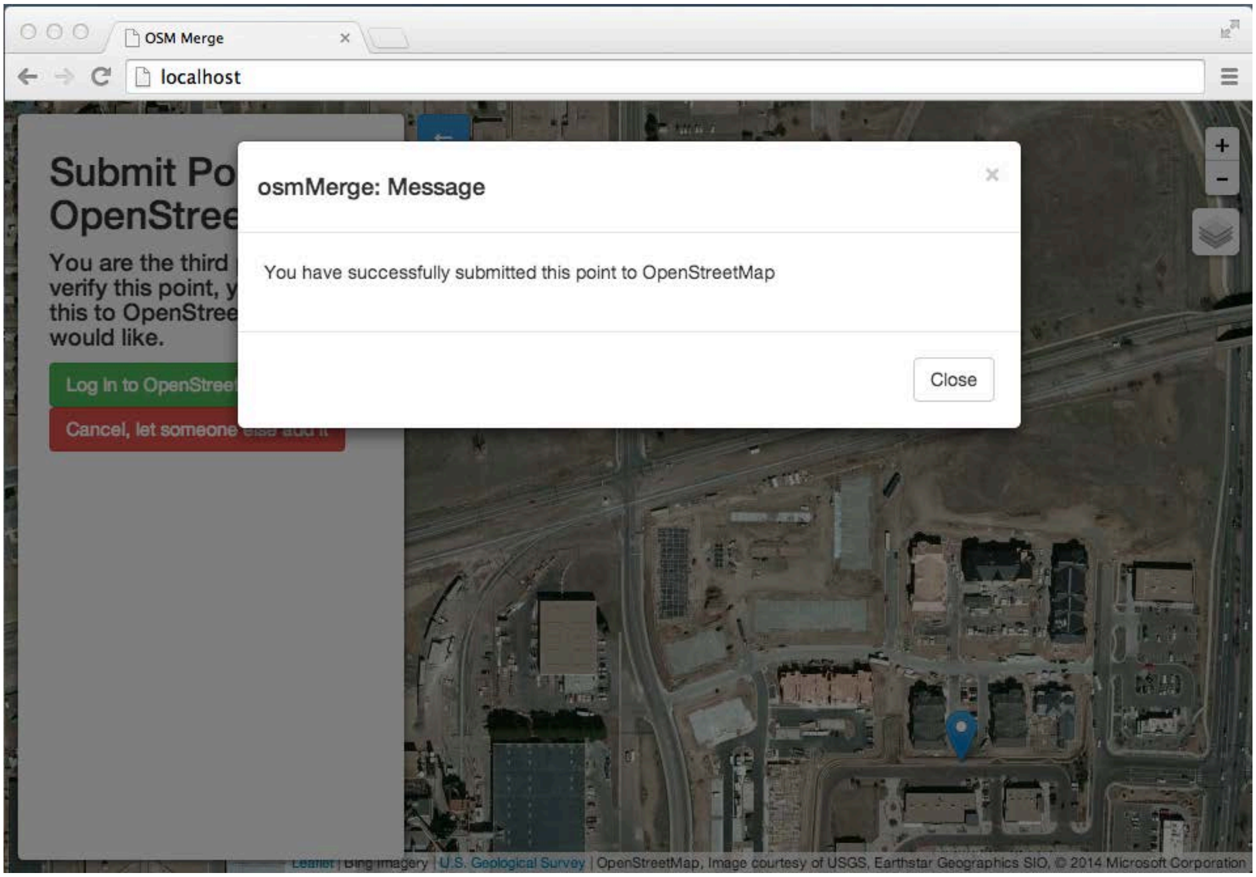

Figure A9: Successful submission to OpenStreetMap

Source Code for this project can be found at:
https://github.com/jimmyrocks/osmmerge

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