Utilizing Volunteer Geographic Information to Update The City of Colorado Springs Trails

Travis Rehder

University of Colorado Colorado Springs

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Introduction

Delayed spatial data collection in our parks has resulted trail erosion, deferred maintenance, and higher repair costs for volunteer workers. However, to address some of these issues, recently, one person has been hired by the Parks Department to maintain and update the Parks GIS data. The recession of 2008 took its toll on The City of Colorado Springs just as it did for many other cities in the United States (www.Gazette.com). City Departments lost funding to maintain daily operations and to hire new employees. Most dramatically, there was a significant loss of institutional knowledge and talent when the City of Colorado Springs implemented Reduction-in-Force (RIF) policies during the recession. Hundreds of employees were laid off over the last six years, ninety of them alone, lost jobs 2009 (Vogrin, 2009). In the Geographic Information Systems (GIS) department the workforce was reduced from 12 employees to 4 employees. This reduction included the person who was responsible for maintaining the GIS data for the Parks department (Zubeck, 2008). The large RIF left the responsibility and support of maintenance of GIS data for the entire city to four people. This GIS support includes, but is not limited to the following departments: Fire, Police, Parks, Engineering, Planning, the City Clerk, City Legal Counsel, Real Estate, and the Mayor’s office. In addition to departmental support GIS is also responsible for taking on extra projects that arise. Needless to say GIS resources in the City of Colorado Springs have been constrained. This lack of resources has caused the aforementioned issues within our local trail system.

This project will illustrate how resource constrained municipalities can use the general public to source data to assist with park and trail maintenance, planning, and future development with very little cost. Crowdsourcing and, more specifically, its close ally Volunteered Geographic Information (VGI), offer the opportunity for a private/public alliance to assess the trails in Palmer Park (Goodchild, 2007). Using a sample of VGI data collected with a commercially available GPS from mountain biking and hiking, a comparison map was be made to show differences between the perceived uses of trails compared to the actual use of the trails in Palmer Park. Findings indicate that the VGI data shows differences between the parks official trails data and how users actually interact with the park.

Literature Review

The literature on the challenges faced by local governments to maintain infrastructure, create new infrastructure, and work with the public on these topics is vast. The following chapter narrows those topics to include information relevant to trails maintenance and crowdsourcing as it applies to this project. The literature in the following areas is briefly summarized to demonstrate the potential for public/private cooperation through the use of VGI. First is an overview of the problem of social trails in parks. Followed by a brief history of crowdsourcing and how it is contained within the theory of social networking.

Social Trails

"Many urban and suburban recreation areas suffer from high visitor density and multiple uses, leading to exceeded social carrying capacities and use displacement" (Reichhart el at, 2007). Social carrying capacity is where the level of use exceeds acceptable levels defined by evaluative standards (Reichhart el at, 2007). The Visitor Experience and Resource Protection (VERP) framework is an evaluative standard. Use displacement due to exceeding the carrying capacities of the recreational area in turn creates social trails. Jeffrey Marion et al. (2006) define social trails as visitor-created trails in parks. Additionally, Lisa Maloney (2007) points out that social trails "spring up as the unplanned result of regular foot [or bike] traffic". Maloney (2007) goes further to explain that social trails "almost always represent the most direct path—or at least the path of least resistance—to some goal. This definition of a social trail allows for any trail that is not in the official trail data to be considered a social trail. Problems arise due to social trails because of visitor traffic within parks can "compact soils, widen trails, exacerbate problems with muddiness, and accelerate soil erosion" along with "trampled plants to removal of entire plant communities" (Marion et al, 2006; Rochefort and Swinney, 2000). Social trails are a concern for the park administration due to resource constraints to maintain and fix city owned parks.

Social Network Theory and Crowdsourcing

Social Network Theory (SNT) strives to study and understand how people, groups, and organizations interface within their network (Claywell, 2014). A network contains objects or nodes, in this case people, and or maps describe the relationship between the objects (Kadushin, 2004). Three different types of networks have been investigated by social scientists: egocentric, socio-centric, and open-system (Kadushin, 2004). Kadushin states that egocentric networks are those networks that are connected with a single node or individual, and that "open system networks are networks in which the boundaries are not necessarily clear, they are not in a box" (2004). In this project a socio-centric network is in use. Socio-centric networks are networks within a box (Kadushin, 2004). Some examples of socio-center networks are students in a classroom, workers in an organizations, and attendees of a church. Palmer Park is the socio-centric box to study the people, groups, and organizations that interface with the park. Musolesi and Mascolo (2007), point out that validation of networks relies almost exclusively on simulation. The limited amount of real traces in a network lead to using simplistic models that may diverge a great deal from traces that can be obtained by deploying in a real scenario

(Musolesi and Mascolo, 2007). Crowdsourcing has grown out of SNT and offers real scenarios for validation of the network, thus this project provides a validation method of a socio-centric network of the relationship between actual and perceived trail usage of the park in the mountain biking arena.

Howe states that crowdsourcing "is the act of taking a task traditionally performed by a designated agent (such as an employee or a contractor) and outsourcing it by making an open call to an undefined but large group of people" (2008). Requesting information from a larger public group with interest in the subject allows for leveraging the crowd's pocketbook (Howe, 2008). For example, municipalities can obtain GIS data from their constituencies but would not have to supply equipment, e.g. GPS, a bike, or other requirements for mountain biking; therefore, they can harness knowledge and recorded use data of the interested parties with very little investment.

According to Goodchild, crowdsourcing has two different meanings. First, regardless of the group's lack of expertise it can find a solution to a problem more effectively than the expert (2010). Second, information provided by a group is likely to be more accurate than information obtained from a single observer (Goodchild, 2010). Goodchild narrows the idea of the large group of crowdsourcing to a term called VGI (2007). VGI is the engagement of private citizens in the collection and creation of geographic information that has largely been the function of official agencies (Howe, 2007). Some examples of VGI are Google Maps, Flickr, and Wikimapia (Hudson-Smith et al, 2009). Social media sites have also implemented various VGI elements. Facebook and Twitter both want access to the location information from user photos. And other social media sites are constructed primarily from location-based data (e.g. Foursquare, Timehop, Touchtunes, and Yelp. This is often referred to as the social-local-mobile nexus (SoLoMo) (Tilton, 2014).

VGI has shown its value during emergency situations. In May of 2009, the Jesusita Fire started and multiple individuals and groups created map sites combining official information and VGI information (Goodchild, 2010). According to Goodchild, the most popular site "accumulated over 600,000 hits and had provided essential information about the location of the fire, evacuation orders, [and] the locations of emergency shelters" (2010). In addition to emergency response, one can contend that VGI has a place in the day-to-day city management.

Data and Methods

The purpose of this study is to examine the use of VGI for the potential to maintain and update the trails in Palmer Park in Colorado Springs. This is completed through a comparative single subject design using a commercially available GPS unit a comparison map was made to evaluate the differences between the official parks trails data and the VGI data. A map was created using the industry standard mapping suite from Environmental Systems Research Institute (ESRI) that contains following data the current City of Colorado Springs trails, aerial imagery, the parcel composition of Palmer Park, and the VGI data collected. The trails that are not in the City of Colorado Springs trails network are drawn and then added to a new database for comparison. This map creates a visual representation of the difference between what the City of Colorado Springs thinks is happening and what is actually happening in Palmer Park.

Data

A single user operating a Garmin Edge 500 or Edge 510 GPS built the VGI dataset from individual hiking and road/mountain biking events throughout Colorado Springs from 2009 to 2013. GPS is a network of 24 navigational satellites put in space by the U.S. Department of Defense (Garmin, 2014). The original intent of the GPS satellites were for military applications but was made available for civilian use in the 1980's (Garmin, 2014). The GPS units were set to gather data every second to increase the accuracy of the data. No information about the user has been collected. The master data contains over 500 different hikes or rides and 458,241 data collection points. Once the data were collected the scope of the data was narrowed to only include information that had been collected within Palmer Park and one small area just outside the park within in the Colorado Springs city limits. This smaller dataset contains over 100 different rides and 140,170 data collection points.

Data Collection

The data were collected from individual mountain bike rides using the Garmin Edge 500 or Garmin 510 GPS unit, which is a small computer that records location based data. The Garmin was mounted to the handlebars of the mountain bike. During each ride the Garmin used GPS plus the GLONASS (GLObal NAvigation Satellite System) for a higher location accuracy rate. Data recording was set to once every second for more consistent data collection. After each ride the Garmin was downloaded to the Garmin Training Center software on a personal computer. The collection and downloading of these data allows a user to map their ride. This process was repeated over 100 times within the study area from 2009-2013.

GPS

GPS data is a common data type used to create two-dimensional spatial displays so that we can more easily visualize routes taken by the user and the terrain that they covered during activity. Due to the ease of use and data availability, this project utilizes GPS data collected from the Garmin Edge device, which is accessible to the everyday user. The Garmin Edge 510 was chosen for its ease of use and platform of support, which allows the export GPS data into the format used with ESRI. The Garmin Edge GPS is set to record data every second rather than the smart recorder that records data at key points when you change direction (Garmin, 2013). The change to the one-second interval in recording creates a far more detail record of the activity (Garmin, 2013). When available the GLONASS was also used in conjunction with GPS to increase the number of satellites available to the Garmin EDGE GPS. The use of GLONASS along with GPS increases the measured horizontal accuracy to be less than 3 meters compared to the 35-meter accuracy obtained in 2006 (Foster). The total number of satellites available for use is 12 at any given time.

After the activity had been recorded with the Garmin Edge GPS the data were then uploaded to a computer that has the Garmin Training Center freeware installed. The Garmin Training Center then provides the user with a tool to export the data by activity, week, month, year, or all. The data were exported in the GPS Exchange Format (GPX). The GPX files were used because of the compatibility with ArcMap. The GPX files were then exported into a folder that could be accessed by ArcMap to get a usable visual display of the VGI data against the current Palmer Park trails data. In other words, this process allows the creation of a map of the activities that were recorded by the GPS unit.

Python

Python is an open source, interpreted, object-oriented, high-level programming language (www.python.org). PyScripter is a free, open-source Integrated Development Environment (IDE) that was used to process the large number of GPX files to files in a file geodatabase to be used with the ESRI toolset. The GPX_To_Feature.py script was used to iterate through the each file that ends in .gpx in the gpxFolder and converts it to a feature class in the Capstone file geodatabase in outputGdb folder. See appendix for the full script that was used.

ESRI

ArcGIS is an industry Geographic Information System (GIS) suite made by ESRI including ArcGIS for Desktop Advanced (ArcMap and ArcCatalog). The version of ArcMap and ArcCatalog used is 10.2.2 for this process. The procedure to take the VGI in the GPX form and make it usable in ArcMap is as follows:

Open an empty ArcMap map (MXD) session and add the newly created points from the conversion above. The points are then stored in a local file geodatabase. The GPS data will now be in the geographic coordinate system, GCS WGS 1984, and the datum, D WGS 1984 is the current projection for the GPS data. The change to the geographic coordinate system of the GPS data makes it the same as the official city data that it was compared.

The GPS data now must be re-projected to work with the trails and aerial imagery data. The imagery used is provided by the City of Colorado Springs. To do this, an empty ArcMap session was opened and trails and aerial imagery data were added from ArcCatalog. Once the trails data had been loaded, GPS data were added that had been converted earlier through the projection process. The GPS data are then exported to the file geodatabase. If replicating this process, make sure to select the data frame as the coordinate system that should be used for the exported data. After this process, the GPS data should be in the correct projected coordinate system, NAD 1983 State Plane Colorado Central FIPS 0502 Feet, which matches the projected coordinate system of the other layers. The newly projected GPS data were added back to the map and the GPS data that was in the wrong coordinate system was removed.

To continue, the parks polygon layer was added to the MXD and parcels within Palmer Park were selected. The ‘select by location tool’ was implemented to select all of the GPS points that have their centroid within the Palmer Park parcels. Then, a visual examination of all of the

GPS points that were expected to be selected was completed. If all parcels were not represented, then a process of holding down the shift key and selecting the points to add them to the currently selected GPS points would need to be performed. The selected GPS points were exported into the file geodatabase. Once the GPS points were exported, they were added back to the MXD and the points that were no longer relevant to the analysis were removed or turned off. All the selected GPS points from the newly added Palmer Park GPS points were used to create one unified feature class with assistance from the merge tool. This allows us to view one unified feature class rather than each individual activity.

In the file geodatabase a new feature class was created that contains line features and uses the NAD 1983 State Plane Colorado Central FIPS 0502 Feet coordinate system. The default settings were maintained for the rest of the configurations. No new fields needed to be added to the feature class at this time. The result of this process was the creation of a new line feature class.

This new line feature class was added to the MXD along with the aerial imagery, the trails data, and the GPS points. The GPS points were examined to make sure that they were on a trail that is not in the trail data and were not on a road. Then, the new line feature was edited to add data where there was not a trail and that the trail was not on a road. The symbology of the existing trails was set to yellow, new trails were set to red, and purple for the GPS data. This makes them easily seen against the imagery

This process produced an MXD that has imagery, trails, GPS points, and trails drawn from the GPS points. This MXD was used to create a picture of the differences between the official trails and what VGI collected data shows is really happening on the trails. Further uses and information will be discussed in the findings section to follow.

Findings

Many new trails have been observed in the VGI data. Of the trails that have been observed in the VGI data, five trail types have been categorized and are discussed. Figure 1 shows an overview of all of the VGI trails that were collected (in red). Because of space constraints, rather than discuss all of the areas where differences were found, only five that fit the following categories will be discussed. There are VGI trails data that go onto private property, VGI trails data that appear to be a re-alignment of the current trails, VGI trails data that can be seen in the aerial imagery but are not in the City trail data, VGI trails data that cannot be seen in the aerial imagery but are there according to trails data, and VGI trails data that show social or rogue trails that can be seen in the aerial imagery but are not in the city trails data. The maps will be displayed on the aerial imagery with the following features and colors: the Palmer Park boundary in yellow, The City of Colorado Springs official trails in black, private property in blue, and trails found in the VGI data are in red.

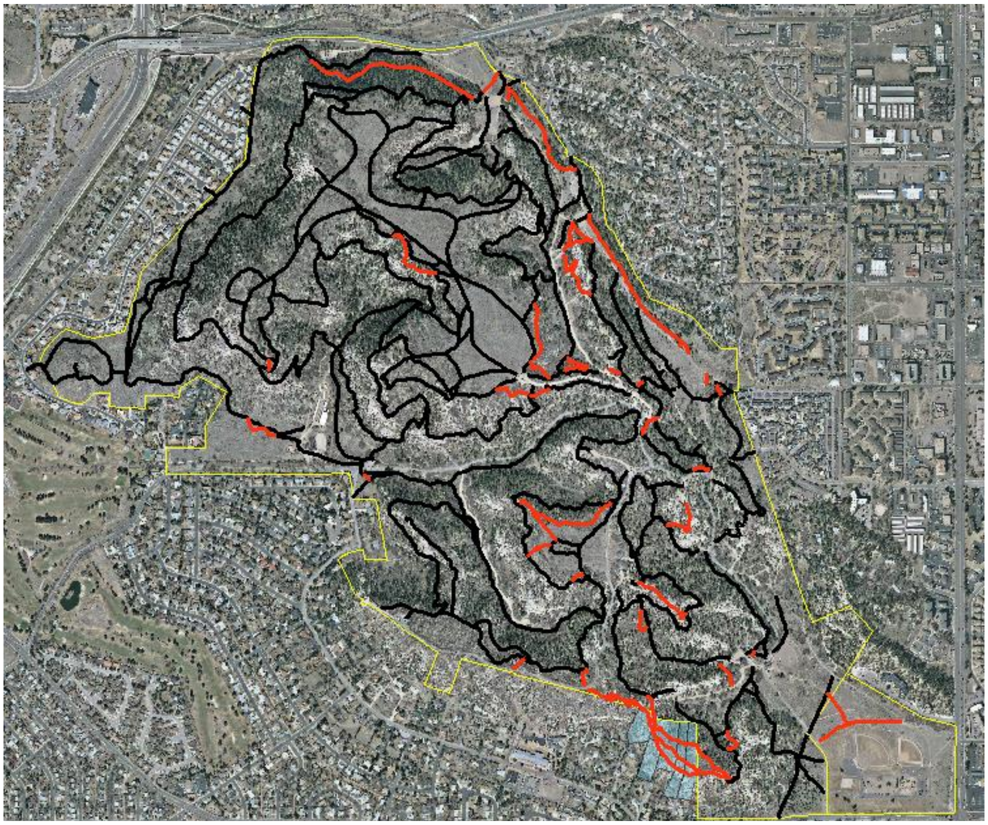

Figure 1: Full Map of Study Area, Palmer Park

Private Property

Figure 2 shows VGI data that originate from the road or other trails in the City of Colorado Springs official trail data that traverse outside the Palmer Park boundary onto private property. The web of VGI trails covers five different parcels that are owned by private citizens. This could be an area of considerable risk of liability to the City of Colorado Springs and to the landowner. If anyone were to get hurt they could sue the City of Colorado Springs and the owner of the parcel for their injuries.

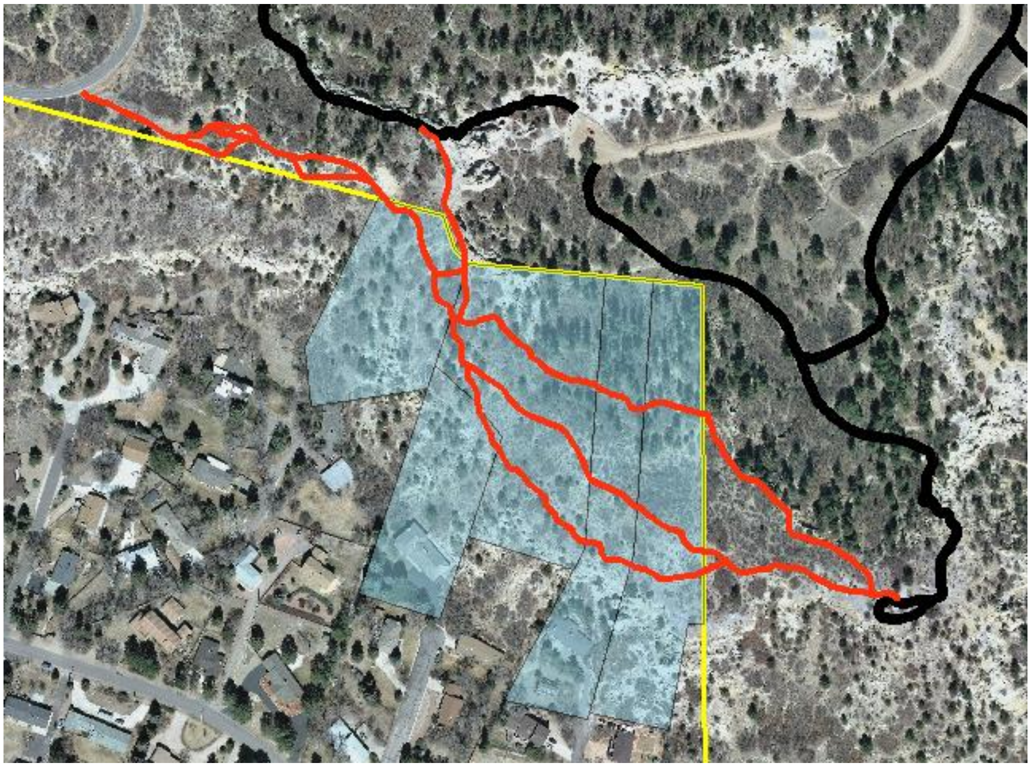

Figure 2: Private Property Encroachment

Trail Realignment

In Figure 3 it can be seen that the VGI data are different from the City of Colorado Springs official trail data. The realignment cannot be seen in the aerial imagery and would have to be visually verified to make sure that it is not an error in the VGI data.

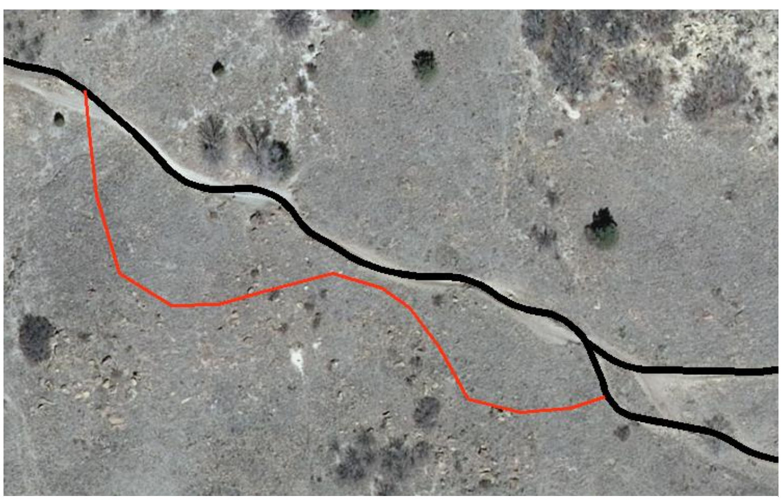

Figure 3: Trail Realignment, Example 1

Figure 4 shows a change in the trail from the City of Colorado Springs official trail data and the VGI data. Part of the VGI data appears to be in the aerial imagery though some seems to be obscured by the trees. In this case the VGI data would have to be visually verified or someone from the Parks department with knowledge of a trail realignment would have verify that the trail has been changed.

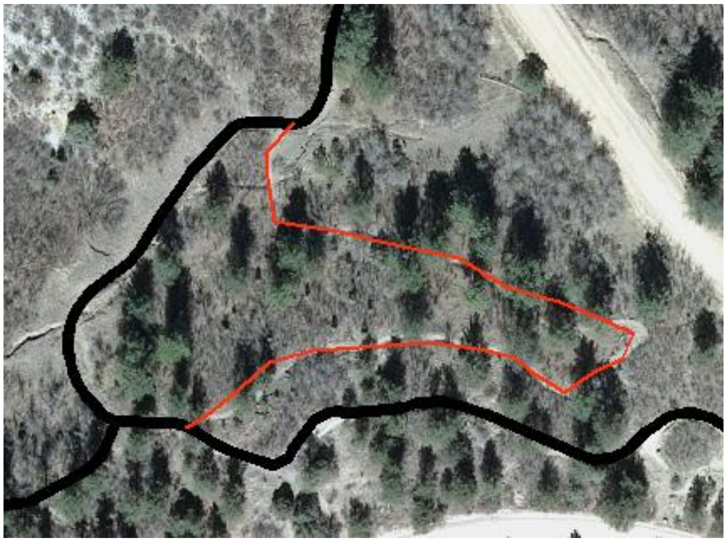

Figure 4: Trail Realignment, Example 2

Figure 5 shows VGI data that originates from known City of Colorado Springs official trails and can be seen in the aerial imagery but is not in the City of Colorado Springs official trails data. The trail is well within the Palmer Park boundaries.

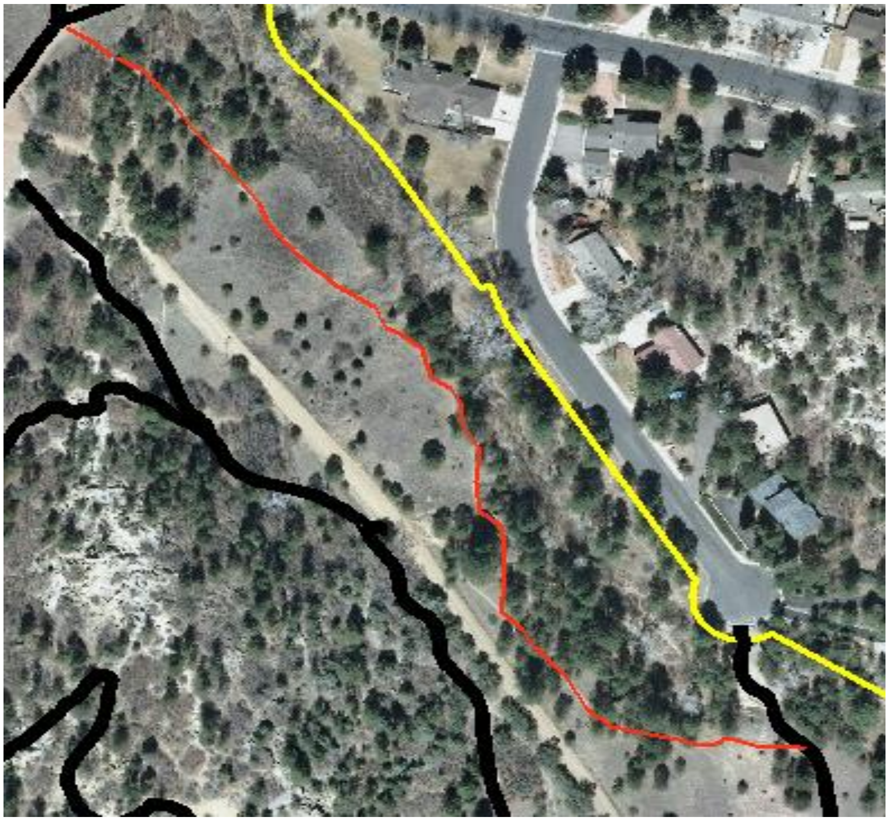

Figure 5: Trail Viewed in Imagery

VGI Trail Not Seen in Aerial Imagery

Figure 6 shows a VGI trail that originates from and ends with the official City of Colorado Springs official trails data. The trail cannot be seen through the tree to gain a visual verification of the existence using the aerial imagery. The VGI trail is too consistent to not be a trail. The VGI trail is also too far away from any other trail to be an error in the Garmin GPS.

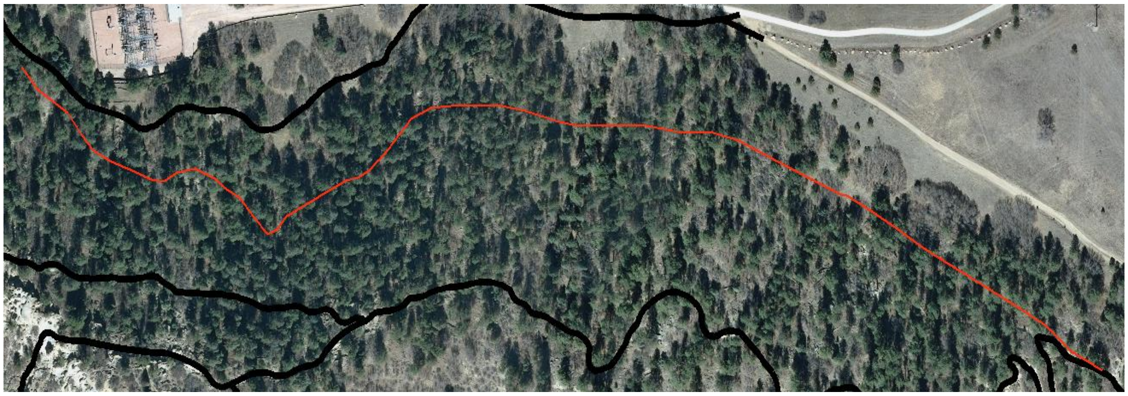

Figure 6: Trail Not Seen in Aerial Imagery

Social Trails

This idea of a social trail is clearly expressed in Figure 7. The VGI trail can be clearly seen in the aerial imagery going from the road to the City of Colorado Springs official trial. Or, vice versa, from the official trail to the road. It shows the most direct, path of least resistance to the official trail to the road or from the road to the trail.

Figure 7: Social Trail

This research and analysis demonstrates there are numerous VGI trails data that go onto private property, show trail realignments, that are in the aerial imagery but not in the City of Colorado Springs official trials data; that are not in the aerial imagery but not in the City of Colorado Springs official trails data; and many, many, social trails that are not accounted for creating a spider web of new trails that could be added to the City of Colorado Springs official trails data. Using the VGI data collected the City of Colorado Springs could add 4.1 miles of new trails to the official trails data. The collected VGI data helps to leverage the limited resources that the parks department has to maintain the city trails data.

Implications of Findings

Several new trails were found as a result of the VGI data, collected during this study. These new trails that differ from the official trails data provide an opportunity for the parks department to examine their operations practice. As noted in the results, five main areas that are of concern for the parks department include: trails on private property, social trails, atrial realignment, maintenance for unknown trails, and safety on unidentified trails.

For example, the trails that run through the private property could be an area of considerable risk of liability to the City of Colorado Springs and to the landowner. If anyone were to get hurt they could sue the City of Colorado Springs and the owner of the parcel for their injuries. The VGI data demonstrate there were at least four trail networks that encroach on private property. Trail re-alignment and social trails create issues with erosion on the park trails. According to the National Park Service, this is a liability issue as a trail realignment could “address visitor safety risks, resource damage, [or] an unsustainable trail design” (2014). The VGI data show two different areas where trail realignment has taken place. Additionally, social trails can be problematic. Due to the nature of social trials, which provide the most direct route to a goal, we can observe compaction of soils, trail widening, and erosion. In other words, social trails occur due to the lack of planning and maintenance of the area (Marion et al, 2006). The trails that can be seen in the imagery and the trails that cannot be seen in the imagery create their own set of challenges. The trails are not maintained because they are not know to the parks department; therefore, if someone were to get hurt there is no map or location information available to emergency workers. According to premises in SNT, Palmer Park is a common social attribute that all of the users have. This common social attribute is called homophily (Kadushin, 2004). Homophily provides a common parallel between this study and the findings in other studies framed by SNT and crowdsourcing. Goodchild (2007) provides the closest link. In the Project GLOBE investigation school children and their teachers, worldwide, are crowdsourcing respondents and provide a source of high-quality atmospheric observations to improve our understanding of global climate change. Likewise, this study demonstrates how regular users of Palmer Park trails can contribute in the same way to the shifting knowledge of trails within Palmer Park.

There are 547 parks that are owned or leased to the City of Colorado Springs. By far, the majority of those parks are neighborhood parks including playground equipment, courts to play basketball or tennis, inline hockey rinks, and fields to play soccer or baseball/softball. Each one of the parks has its own social network that cares about the park. The parks that would gain the most from analyzing VGI are the 12 large regional parks like Palmer Park, Ute Valley, and North Cheyenne Canon Park and the large open space areas like Section 16 and Red Rock Canyon. Each of these parks and open spaces has a friend group or user group that is passionate about the park/open space and want to contribute to the betterment of Colorado Springs open spaces. Incorporating VGI can help focus the efforts of the friends/user groups in the following ways:

- Friend and user groups are willing to do manual labor in the park or open space that the care about. This could include mitigation of trail erosion from social trails or planned trails by filling in the trail with new soil; removing rocks that have made their way into the trail from heavy rains. It also may include the removal of fallen trees across trails by cutting them with equipment like a chain saw or simply rolling them off of the trail. VGI data helps identify areas that need this type of maintenance.
- Applying the VGI data to the trail systems in any one of the parks or open spaces could aid the parks administration in closing social trails that do not meet the standards of the department. As discussed earlier, social trails are a great concern because of the lack of planning that went into creating the trail. This type of trail, typically, experiences more erosion than planned trails leading to possible injury of the trial user and destruction of the trail network itself.
- Combined with the closing of social trails, VGI data could meet additional needs by identifying places to route new trails where the existing social trails once were. The new trails could meet standards that the parks department wants to promote to include sustainable trails, safety, and erosion control.
- Park and open space cleanup is always an issue. Additionally, focusing the passion of the friends groups is an ongoing task. VGI can assist to identify places that require trash collection, equipment maintenance, and structural repairs. This will allow for better communication with friends groups and more efficient maintenance management.

These are just a few ways that VGI could be incorporated into guiding the friends and user groups. Maps of the locations that need work could also be delivered through web-enabled devices like a smart phone or a tablet; removing the guesswork of trying to find the area to be worked on. Photographic records of work being performed could be recorded and cataloged using the location information from the smart phone or tablet photos. These photos could be collect as VGI and incorporated into documents or web applications showing the number, scope, and effort of projects done by friend and user groups. The recording and cataloging of trails work could have the effect of strengthening the public/private partnership.

Limitations

Although the results of this project show differences between the official parks trail information. The project has limitations. The VGI data were only collected by one participant; therefore, the participant's habits could potentially reflect bias because of person hiking or riding habits. In the future this bias can be eliminated by incorporating a model that retrieves data from a statistical sample of hiking and riding participants. Moreover, future research that included such data will provide additional evidence that justifies VGI data is an effective method for evaluating the differences between the official parks trail information and actual trails usage. Another limitation is that data were only collected through hiking and biking activities. The study area includes multi-use trails; therefor, in future research other parks activities such as equestrian use and trail running should be included to show a comprehensive illustration of how the parks trail are actually used by a diverse population.

Future Work

Several other departments within the city infrastructure can benefit immediately from the practice of data gathering via crowdsourcing. The engineering department and planning department are prime candidates for VGI data benefits. For instance, the engineering department has an opportunity to integrate crowdsourcing and VGI into their decision making process. As a primary example, the engineering department created a bike map using shoulder width, traffic volume, and current bike lanes as the variables for bike use: http://www.springsgov.com/SIB/files/2014_Bike_System_Map.pdf. While stakeholder meetings were held to try and better understand how the bike lane system is used, there was no actual crowdsourced VGI data incorporated into the planning process; therefore, the bike map was created without actual use data. If regular bicycle commuters had been asked to contribute data that reflected their actual daily riding routes, two of several issues could be avoided:

   - Disconnected routes: The paved and unpaved trails along with the streets with bike facilities are disconnected and incomplete, by incorporating VGI data traffic engineers might be tempted to connect the disconnected segments in the most direct way. VGI would show how users connect the disconnected segments (used routes). Additionally, pedestrians may not go the most direct way for diverse reasons (e.g. they do not feel safe, no shoulder, or geographic impediments like a hill). VGI data could help identify these reasons.

- Bike lane costs: VGI could provide a better use of departmental budgets. For example, the Senior Traffic Planner with the City of Colorado Springs, Tim Roberts, stated that the cost of painting a bike lane is $3.00 per linear foot (personal communication, 2014). It costs $15,840 for every mile of bike lane per side that is put in. Using VGI may be more a more effective way to choose which streets have bike lanes painted based on actual use recorded with VGI data as a quantifiable addition to traditional methods of needs assessment.

Additional studies that look at these two issues should be scheduled for both resource savings and efficiencies within the city general fund budget.

Conclusion

This study shows that incorporating VGI into the overall strategy of the City of Colorado Springs, Parks, Recreation and Cultural Services Department can help leverage the limited resources available. It leverages the power of the single GIS analyst that the Parks department has by incorporating VGI data from 100's or 1000's of potential users to create a better understanding of the trail network in the City's parks. SNT and VGI creates the opportunity for a private/public partnership that can benefit all of the park users. The City of Colorado Springs can better guide their friend's groups to maintain and restore trails. Social trails that create safety risks, resource damage, and have unsustainable trail designs can be realigned or closed altogether (National Park Service, 2014). The VGI data gathered by a crowd of many observers is likely to be closer to the truth than information obtained from one observer (Goodchild and Glennon, 2010) leading to excellent information about the actual park trail usage compared to the perceived park trail usage.

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Appendix

Python Script

```
import arcpy
from os.path import isfile, join
from arcpy import env
arcpy.env.overwriteOutput = True
gpxFolder = 'C:/Projects/Capstone/garmin/'
outputGdb = 'C:/Projects/Capstone/garminshp/CapstoneGPXProjected.gdb/'
env.workspace =gpxFolder
def convertGPX2feature(gpxFolder, outputGdb):
  for file in arcpy.ListFiles("*.gpx"):
    # Convert files from .gpx to feature layer
    inGPX = gpxFolder + "\\" + file
    arcpy.AddMessage(inGPX)
    featureName = file.partition(".gpx")[0]
    outfile = outputGdb + "\\" + featureName
    arcpy.AddMessage(outfile)
    arcpy.GPXtoFeatures_conversion(inGPX,outfile)
```

```
if __name__ == "__main__":
    convertGPX2feature(gpxFolder, outputGdb)
```