# Evaluation of Augmented Reality Systems for the Enhancement of Voluntary Geographic Information

*Full papers*

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## Abstract

Volunteered Geographic Information (VGI) describes the volunteering of geographic information by users of systems that enhance their ability to produce data. Web 2.0 and mobile technologies enhanced the adoption of VGI. Similarly emerging technologies such as Augmented Reality (AR) may further enhance VGI. AR may provide a novel means for enhancing VGI and the types of contributions users are able to make. To explore this, a literature review is provided that examines both VGI and AR. Factors that may contribute to the adoption of VGI are identified along with ways AR may enhance VGI. These factors are then examined in commercial AR applications and the results are presented. An additional pilot study is also performed to gauge user perceptions of VGI in AR. The results suggest that while progress is being made in AR that may enhance VGI, current AR systems still do not take advantage of their full potential.

**Keywords**

Augmented Reality, Volunteered Geographic Information Systems, Adoption

## Introduction

The enhancement of Volunteered Geographic Information (VGI) can potentially change the way people view the world. As technology such as Web 2.0 has matured more users have begun to experiment with online mapping systems. The integration of new technologies with Geographic Information Systems (GIS) have changed the role of users from consumers of Geographic Information (GI) to producers. This shift can help aid in the empowerment of marginalized groups while also improving the quality of services that governments are able to provide (Elwood 2008). With emerging technologies such as Augmented Reality (AR) on the horizon it is important to examine how they can further shape the way people share GI.

Similar to the way that Web 2.0 transformed GIS, new technologies such as AR may further transform the way users contribute VGI. However content generation is seldom a focus of AR research (Wither et al. 2009). Some researchers have suggested that mobile devices and technology such as Web 2.0 can lead to greater AR usage and innovation (Schmalstieg et al. 2011). This study examines how user production of VGI can potentially be enhanced in AR environments. In order to accomplish this, a literature review was conducted to examine ways that VGI has been enhanced by mobile and Web 2.0 technology. Commercial AR applications are then examined to see if they share similar features and challenges towards their adoption for VGI. Finally a pilot is performed to examine whether users perceive AR applications as VGI.

## Volunteered Geographic Information

### *What is VGI?*

The term VGI is used to describe the creation of location based information by users on a voluntary basis. More specifically, VGI refers to a phenomenon where users are transitioning from merely consumers of geospatial content to producers as well (Goodchild 2007a). As Geographic Information Systems (GIS) have been adopted for use with Web 2.0 technologies the wikification of GIS has been observed (Sui 2008). GIS has changed from complex systems where content and applications are primarily the domain of expert users, into more open systems that allow contributions from non-expert users.

User roles in older GIS models were dependant on a users' expertise. Non-expert users were primarily consumers of GIS content, while experts were generally the producers of both content and the applications. GIS have often been criticized for their complexity and the difficulties that prevent adoption by non-professional users (Haklay and Tobón 2003). Although there have been exceptions, generally geospatial data has been produced by authoritative sources using complex systems (Goodchild 2007a). Non-expert users are usually the consumers of this content.

VGI has become of increasing interest to researchers because of what has been seen as a neo-geography that changes who can become a producer of geospatial content and applications (Goodchild 2009). This has been due in part to the prevalence of new tools powered by Web 2.0 and mobile technology.

## *Active vs Passive production*

New technologies have enabled users to produce GI in a variety of different ways including both actively and passively. With active production user interactions with a device are directly translated into geographic data. For example a user using the Open Street Map (OSM) application might draw a polygon on a map by using a mouse directly (Haklay and Weber 2008). In contrast, with passive production, a device may collect location data at the request of a user with little direct interaction. For instance devices equipped with Global Positioning System (GPS) technology can retrieve continuous updates on a user's location. These updates can be stored and tracked to create location information on the path a user is traveling. In this case the user does not have to actively provide information, but can passively allow the device to obtain it. Mobile applications such as Waze take advantage of passive data production in this manner (Waze 2015).

Because passive production can be done without users' knowledge, there have been questions raised over the extent to which it may count as VGI (Elwood et al. 2012). Some applications can acquire and use data that users are not consciously aware of sharing. But not all passive data collection is done without users' knowledge. Waze for example passively tracks a user's movement and collects location data (Waze 2015). By default, when Waze is run, it begins collecting data passively. Users are also able to actively add data on locations during their travels. This combination of passive and active data contributions are used to map and suggest routes for users. Although Waze informs users that passive contributions are required, it is uncertain to what extent users may be consciously aware that they are contributing information. Yet, users are voluntarily contributing to the broader geographic knowledge (Elwood et al. 2012). Other applications such as Swarm allow users to enable passive data sharing and disable it at will (Swarm 2015). Users themselves can voluntarily determine when to passively share data. Regardless of whether these applications can be considered true VGI or not, passive sharing of data should be considered for the design of VGI applications.

## *Primary and Secondary Usage*

In some cases users take on the role of primary producers of content. Applications such as Swarm and Waze rely on geospatial content generated by users (Swarm 2015; Waze 2015). Volunteered contributions also make up the core of OSM data (Haklay and Weber 2008). While production of data can be either active or passive, in all of these cases VGI is a part of users' primary interaction with the applications. For these systems the primary goals for users in interacting with these applications are to acquire or share VGI data.

There are also applications where volunteering geospatial data is a secondary user goal. In these cases the data users share is optional and is not the applications primary purpose. Many applications provide geotagging and other map based services as secondary features. Flickr for example, is an example of VGI discussed in the literature (Elwood et al. 2012; Sun et al. 2013). While users of Flickr can volunteer GI by geotagging images, this is not likely the primary goal for most users. Geotagging and storing geotagged images in Flickr is generally presented as a secondary or optional feature. Facebook also allows users to geotag photos and posts. However social networking rather than accessing or contributing geospatial information is the primary user goal (Facebook 2015). This use of VGI as a secondary feature is different than applications such as OSM or Wikimapia where the purpose is to allow users to share and contribute VGI (Goodchild 2007e; Haklay and Weber 2008; Wikimapia 2015).

## *Trialability, Usability and Extensibility*

Technologies have helped users that do not have high levels of expertise to become producers of geospatial content and applications. Advances in Web 2.0 technology have allowed the creation of web mapping tools that are similar to desktop GIS applications (Haklay et al. 2008). This has brought GIS capabilities to a wider audience and also provided usable and extensible map interfaces for users to experiment with. Through the use of open data services and platforms users have begun creating their own GIS applications. Trialability, usability, and extensibility have played a role in the growing adoption of VGI.

New technologies have increased the trialability of GIS. Traditional Desktop GIS applications have often been viewed as inaccessible to most users due to their costs and complexity (Haklay and Tobón 2003). Yet applications such as Google Maps and others have been relatively free and accessible for users with existing Internet connections. Further mobile devices with embedded GPS capabilities are now commonly used. Unlike traditional desktop GIS, users of mobile and web applications are able to quickly access vast amounts of geospatial data without having to go through complex installation procedures or data acquisitions (Goodchild 2007a; Sui 2008). While some of these tools may not provide advanced GIS features, they do enhance the trialability of applications. This allows users to become more familiar with software by observing its benefits and ultimately helps encourage adoption (Rogers 1995).

Technologies have enhanced the usability of web mapping tools by simplifying their functionality. As mentioned, one of the main challenges to user adoption of GIS software is their complexity and the difficulty for non-experts to use them (Haklay and Tobón 2003). One of the main advantages of VGI through web mapping applications is that advanced geographic knowledge is not needed to contribute data. For example many web applications do not require knowledge of different geographic coordinate systems (Goodchild 2007a). While this eliminated some functionality, studies show that users may not desire complex applications and might be drawn to more simplistic designs with readily available functionality (Skarlatidou and Haklay 2006). This can be seen in mobile applications that automatically acquire a user's location for navigation purposes. The lack of complexity and user familiarity with these applications may have aided in their adoption (Davis 1989; Rogers 1995).

VGI adoption can also be attributed to the ability of users to extend mapping applications using common platforms and open source tools. Innovations typically go through a process of re-invention during their adoption as users modify it to suit their needs (Rogers 1995). As users experimented with web mapping applications they began to take advantage of Web 2.0 technologies and underlying server data to create mashups (Haklay et al. 2008; Miller 2006). Mashups integrate data from different web applications into a single unified interface. Map mashups became a popular way for users to create GI. As a result many creators of map applications began releasing application programming interfaces (API) that help users to create new applications that use their services (Yee 2008). This allowed simple map applications to be extended to fit different needs and allow new users to experience the underlying services. The services are not only accessible through web interfaces but also on mobile platforms. The Android platform, for instance, provides access to both existing map and location based services (Rogers et al. 2009).

## *User Motivations*

The motivations of users for contributing data have been of interest to researchers investigating VGI (Budhathoki 2010; Budhathoki and Haythornthwaite 2013; Coleman et al. 2009). Understanding these motivations can assist developers in creating systems that further encourage participation (Budhathoki and Haythornthwaite 2013). This is important as motivations can change and different categories of users may have different motives for participation (Budhathoki and Haythornthwaite 2013; Coleman et al. 2009).

Coleman et al. (2009) describes both constructive and negative motivations for users to contribute VGI. Constructive motivations are those used to create new and enhance existing content. Negative motivations are those that lead users to attempt to purposely supply inaccurate information or lessen the value of existing information. Budhathoki and Haythornthwaite (2013) present two different groups based on intrinsic and extrinsic motivations. Intrinsic motivations are defined as those in which the activity itself becomes part of the reward whereas extrinsic motivations are those that come from outside the person.

### *Quality of Data and Contributors*

A number of questions have been raised about the quality of VGI contributions (Goodchild and Li 2012). Unlike authoritative data sources, few VGI sources provide quality controls (Coleman 2013; Goodchild and Li 2012). VGI providers seldom offer any guarantees on the quality, reliability and value of data (Flanagin and Metzger 2008). Despite the lack of guarantees on data quality, studies that have compared OSM with authoritative sources show an above average overlap between the two (Haklay 2010). While there is a high degree of overlap there are also differences in the data. Some of these differences can result from errors. Errors can not only include mistakes but can sometimes be intentional or result from omissions (Devillers and Jeansoulin 2006; Haklay 2010). For example a common issue with VGI is the incompleteness of data (Haklay 2010). Errors can also arise from a variety of sources such as hardware components or the lack of user capabilities (Jackson et al. 2013).

The quality of data can also be impacted by a lack of skills and expertise by contributors (Grira et al. 2010). Contributors can also have difficulty with relating information to a location (Jackson et al. 2013). This presents a challenge, as one of the benefits of VGI systems is seen as its ability to enable non-experts to become producers of geospatial data (Goodchild 2009).

While VGI has increased the number of geodata contributors, neogeography is not completely democratized (Haklay 2013). New technologies may only have shifted the class of producers to include those with technical skills as opposed to just geographic expertise. Questions still remain on how to enhance GIS and VGI for greater participation, especially for marginalized groups (Tulloch 2008).

## Augmented Reality

### *What is AR?*

Augmented Reality (AR) is a term used describe the combining of real and virtual worlds in a real-time interactive environment (Azuma et al. 2001; Azuma 1997). In AR users remain immersed in the real world while interacting with virtual elements. Unlike in other environments AR allows users to interact with both virtual objects and the physical world in real time. Different technologies may be used to implement AR.

AR visuals can be created using different display devices such as cellphones, head mounted displays (HMD), and projection based devices (Zhou et al. 2008). Each device has advantages and disadvantages. For example cell phones can be used to display AR using a "looking glass" approach (Looser et al. 2004). However when a user stops looking at the AR interface they leave the augmented environment. In contrast a user of an HMD remains in the augmented world as long as they wear the display.

There are still no commonly accepted means of inputting data into AR (Van Krevelen and Poelman 2010). Some researchers recommend the combination of gesture and speech to create natural modes of interaction (Billinghurst and Lee 2012). Others suggest that new devices such as wearables may provide other means for input (Höllerer and Feiner 2004).

AR can enable a variety of different user experiences. While the goals of AR is to provide a 3d interactive environment, data and interfaces can also be presented in 2d (Azuma 1997; Feiner et al. 1993). Users of AR can experience these interactions while both stationary and mobile (Höllerer and Feiner 2004). Although there is still research being conducted on technical challenges in the implementation of AR there are a variety of application areas that can potentially benefit from AR (Van Krevelen and Poelman 2010; Zhou et al. 2008).

### *Augmented Reality for VGI*

Similar to the way technologies transformed the way users interact with GIS, it is possible that technology innovations can enhance the way users contribute VGI (Goetz and Zipf 2013). Unlike other environments, AR can provide the ability for users to view data in the real world. This may encourage users to contribute different types of information and allow them to contribute more detailed data including information about real and virtual objects. Information may not only be textual but can include 3d objects and annotations.

Research has shown a variety of ways that AR can be used to enhance location data. AR users can not only leave geotagged messages but can also annotate real world objects (Rose et al. 1995). Users of mobile AR are also able to travel through an area while supplying location information for a variety of fields including geography (Höllerer and Feiner 2004). An advantage of AR is the ability to view virtual data while simultaneously interacting with the physical environment and creating additional information.

While the annotation of real and virtual objects is possible in AR there are still challenges to its implementation. The creation of online content in AR has been an area that has been traditionally under explored (Wither et al. 2009). According to Wither et al. (2009) much of AR content generation is performed offline or using tools, like desktop computers, that are not within the AR environment.

The diffusion of mobile phone technology has enabled more groups to begin experimenting with AR and online content creation. In AR 2.0, Schmalstieg et al. (2011) describes the potential for AR growth and adoption through the use of technologies like Web 2.0. According to them mobile phones can provide inexpensive devices for realizing AR. There are currently a number of AR phone applications that have been commercially released with varying success (Olsson and Salo 2011). Due to a limited number of current AR users ways to link AR to current online data services including existing VGI sources have been of growing interest (Belimpasakis et al. 2010) but custom geospatial systems are also common(Garnero et al. 2013).

## Methodology

There are two parts to this study. In the first part commercial AR applications were examined in relation to the factors identified in the literature review. The second part is based on a pilot study that examines how users perceive VGI in existing AR applications.

AR may provide a novel approach for VGI but it is unclear what impact the use of AR may have on VGI. To explore this, the first part of this study examines a collection of existing AR applications for factors identified in the literature. These include active vs passive production, primary and secondary usage, trialability, extensibility, data quality, contributor quality, 2d/3d content generation, 2d/3d visualization, and existing vs custom sources. Usability and user motivations are left for future research.

A distinction is made between primary and secondary user created geographic content and user created content. This is made to examine whether AR applications that focus on User Content Generation (UCG) may or may not have a geographic focus. Because many of the applications examined are considered AR browsers, the definition of users includes 3rd party developers.

The applications for the first study were selected based on those identified by Olsson and Salo (2011. Information about the applications was gathered by using the application, documentation and the application's website. Applications that did not allow user contributions directly through the application, APIs or external applications are not examined. Contributions are considered those that create or edit information or objects that are associated with some geographic location. Out of 34 applications from the research paper examined only 10 fit the criteria.

In addition a pilot study was performed that examined user perceptions of VGI in AR applications. For the pilot study 10 participants, 6 male and 4 female, were recruited from the university. Of the participants 1 made an error in the questionnaire by placing two checks for one question and missing a check for another. As the rest of the results were valid, only the errors were discarded.

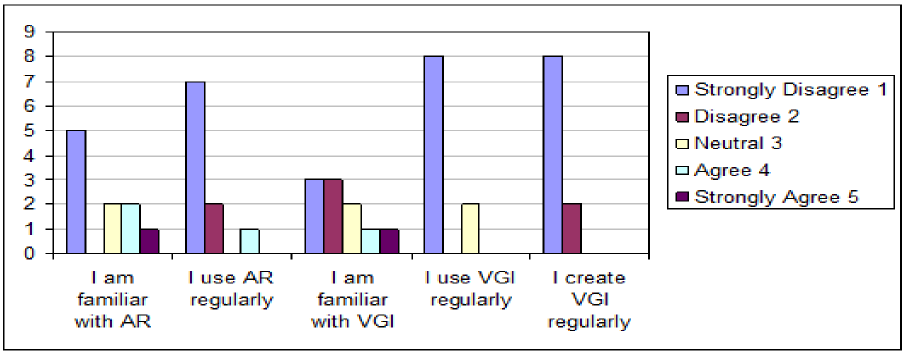


**Figure 1: Participant familiarity with AR and VGI**

Participants were given 5 mobile applications to test. The application order was chosen using a random number generator. Participants were given 5 minutes to explore the application and familiarize themselves with its functionality. After testing an application participants were given a 3 part questionnaire.

The first part provided a definition of VGI from Elwood (2008). Participants were asked to read the definition and rate their agreement with 3 statements. The statements chosen included whether the application uses VGI, whether users can use the application to create VGI and whether users would like to use the application for VGI.

In the second part participants were provided 4 statements to rate. The first 2 statements checked if participants felt that the primary purpose of the application was to create user content and VGI. The next 2 statements examined whether participants felt they were easily able to create UCG and VGI. Finally participants were asked to rate whether the application fit a definition for AR based on Azuma et al. (2001).

The applications tested for the pilot study included Layar, Mixare, and Yelp Monocle. These were selected because each allows a different form of UCG. Layar allows offline, Yelp Monocle allows online, and Mixare allows both. The mobile version of OSM served as a control because it is cited as an example of VGI (Haklay 2010). ARTags was used as it provides a front end user interface for Layar that creates location based image "tags". This was used to examine whether explicitly allowing UCG could change perceptions of an applications potential for VGI.

## Results

| Application | Active/Passive | Geographic user content Primary/Secondary | General User content Primary/Secondary |
|---|---|---|---|
| Argon | Active | Primary | Primary |
| Junaio | Active | Secondary | Primary |
| Kafkara | Active | Primary | Primary |
| Layar | Active | Secondary | Primary |
| Mixare | Active | Primary | Primary |
| Yelp Monocle | Active | Secondary | Secondary |
| Wikitude | Active | Secondary | Primary |
| Discontinued | | | |
| Acrossair | Active | Primary | Primary |
| Nokia Point and Find | Active | Secondary | Secondary |
| Sekai Camera | Active | Primary | Primary |

**Table 1: Active/Passive production and Primary/Secondary contributions**

Applications were examined for active and passive production. Active contributions are those in which the user has to actively interact with the interface in order to contribute data. Passive are those that do not require any direct user action but still contribute data. Although almost all AR applications rely on passive location monitoring for positional tracking only those that are used specifically to produce data that contribute to the broader geographic knowledge were categorized as passive (Elwood et al. 2012). There were no applications that used this type of passive production and instead all applications relied on active contributions.

Primary and secondary usage was examined. Geographic user content is considered primary when it is the main focus of the application. Secondary usage is when volunteered geographic content is an optional feature of the application. The results for this are more mixed with some using primary contributions and others secondary.

Applications that allow general UCG were identified. Applications that focused on UCG regardless of whether it was geographic content were labeled Primary. Those that did not were labeled secondary. While most applications have UCG as the primary goal, they do not all allow GI production as a primary feature.

| Application | Trialability | Extensibility |
|---|---|---|
| Argon | Free | API available |
| Junaio | Free for browsers, developer fee, free POI | API available |
| Kafkara | Free | Na |
| Layar | Free for browsers, hosting fee, trial hosting | API available |
| Mixare | Free | Open Source |
| Yelp Monocle | Free | API available but not for Monocle |
| Wikitude | Free for browsers, trail developer, full developer fee | API available |
| Discontinued | | |
| Acrossair | No longer available | Na |
| Nokia Point and Find | No longer available | Na |
| Sekai Camera | No longer available | Na |

**Table 2: Triability and Extensibility**

The applications were examined for trialability and extensibility. Trialability is the ability for users to try out or test an application before an actual commitment is made on whether to adopt it (Rogers 1995). Extensibility was also examined as the literature describes applications such as mashups playing an important role in VGI adoption.

The majority of applications tested provide free versions for users to experiment with. Some applications are no longer available. Among those that are, all allowed users free access to test the applications. But not every application allowed users to freely generate content. Some AR browser applications were geared more towards 3rd party developers than non-expert volunteers. Many of these applications also limited UCG. Some required fees for hosting or for software utilities.

Most of the applications provided some form of API for users to extend the application. Only Mixare was entirely open source. Other applications had limitations on extensibility. Yelp has an API users can use to develop applications similar to Monocle but no API for modifying Monocle itself. Argon is based on open standards.

| Application | Data Quality | Contributor Quality |
|---|---|---|
| Argon | No checks server dependant | Technical Expertise |
| Junaio | No checks individual channels | Technical Expertise |
| Kafkara | No checks | Nonexpert |
| Layar | No checks individual applications | Technical Expertise |
| Mixare | No checks backbone dependant | Technical Expertise |
| Yelp Monocle | No identified checks but reporting | Nonexpert |
| Wikitude | No checks individual applications | Technical Expertise |
| Discontinued | | |
| Acrossair | Na | Nonexpert |
| Nokia Point and Find | Na | Nonexpert |
| Sekai Camera | Na | Nonexpert |

**Table 3: Data and Contributor Quality**

Data quality was examined. Data quality was examined to see whether application providers used any checks to determine the accuracy of contributed data. While some applications allow users to report illegal content, none have checks to verify geospatial information. Some allow developers of applications to provide data quality checks. Others rely on secondary sources such as backbone applications or user provided servers for determining quality.

Three categories for the quality of contributors were examined. These include those with no expertise, geographic expertise, and technical expertise. Non-expert users were considered those with no or limited geographic and technical expertise. Users with geographic expertise are those that may have enough of an understanding of geography to work with different coordinate systems and GIS tools. Those with technical expertise may not have previous geography experience but may be technically proficient enough to create software applications. As many of the geographic coordinate features are included in various APIs and development tools, none of the applications required a need for advanced geographic expertise. While many of the applications allow non-experts to contribute content, many of the AR browser applications require technical expertise.

| Application | 2d/3d Contribution | 2d/3d Visuals |
|---|---|---|
| Argon | Both | Both |
| Junaio | Both | Both |
| Kafkara | 2d | Both |
| Layar | Both | Both |
| Mixare | 2d | 2d |
| Yelp Monocle | 2d | 2d |
| Wikitude | Both | Both |
| Discontinued | | |
| Acrossair | 2d | 2d |
| Nokia Point and Find | 2d | 2d |
| Sekai Camera | 2d | 2d |

**Table 4: 2d/3d contributions and visuals**

The type of content that users are allowed to contribute and the presentation of information were examined. The applications were checked to see whether they used 2d, 3d or both types of content. All the applications allow users to view and generate some form of 2d content. Most of the applications that use both 2d and 3d visuals also allow users some ability to generate both 2d and 3d content. Applications that only display 2d content only allow users to generate 2d content.

| Application | Existing/Custom | Content generation | Offline/Online |
|---|---|---|---|
| Argon | Custom | Custom API | Offline |
| Junaio | Custom | Custom Application or API | Offline |
| Kafkara | Custom | Mobile app | Online |
| Layar | Custom | Custom Application or API | Offline |
| Mixare | Existing | Mobile app and API | Both |
| Yelp Monocle | Existing | Mobile app | Online |
| Wikitude | Custom | Custom Application or API | Offline |
| Discontinued | | | |
| Acrossair | Custom | Mobile app | Online |
| Nokia Point and Find | Custom | Mobile app | Online |
| Sekai Camera | Custom | Mobile app | Online |

**Table 5: Existing/custom geographic services and AR content generation**

The ways content was generated for the applications and whether they used existing or custom services for data was checked. Custom services are described as those that are tied directly to the application. This can include user built servers such as those used by Argon. Existing services are those that might already exist outside of the AR application and are not specifically tied to the AR application. For example Mixare links users directly to other VGI services such as OSM. Yelp Monocle is considered as using an existing service because Yelp does not depend on Monocle.

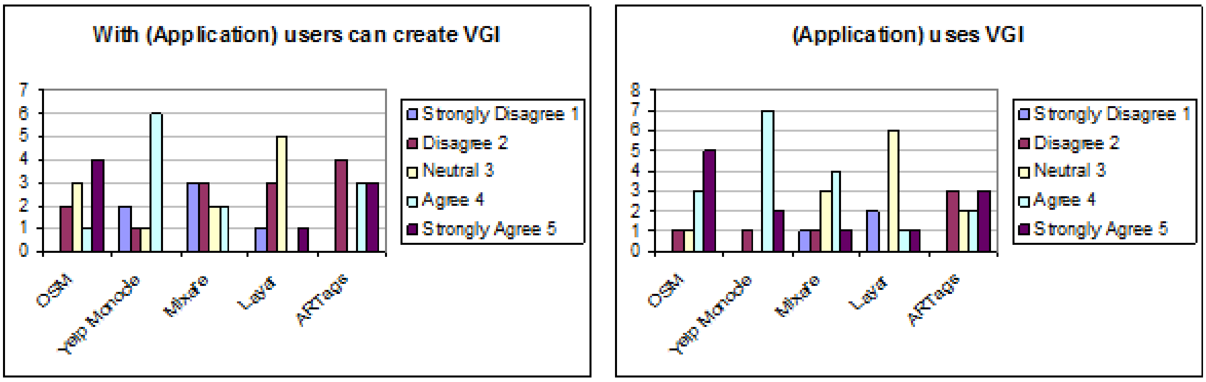


**Figure 2: Participant perceptions of applications use of and ability to create VGI**

Participants had mixed views on whether different applications used and allowed users to create VGI. As expected based on the previous literature most participants did view OSM as using VGI. Among the AR applications Yelp Monacle was also viewed by participants as allowing some form of VGI. Despite Layar being a backend for ARTags, participants had different perceptions of VGI in the two applications.

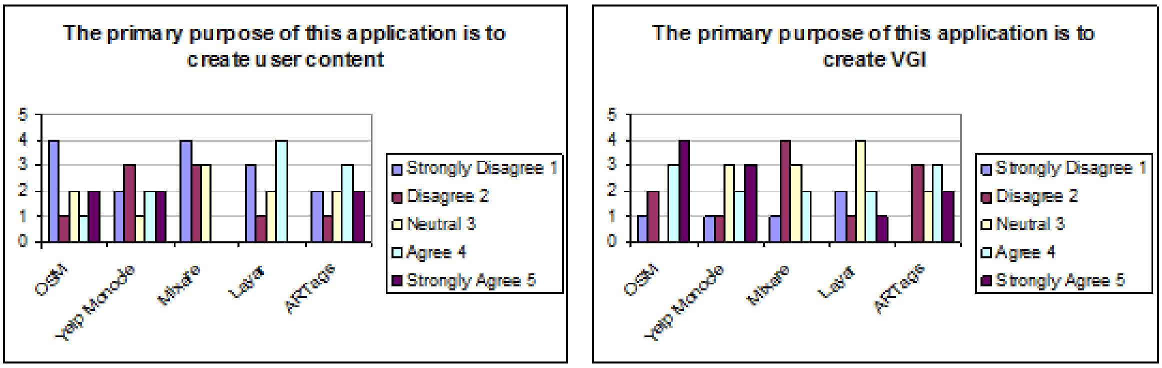


**Figure 3: Participant views on application's use of user content and VGI**

When participant views of the role of user creation of content and VGI in the applications was examined, the results varied based on the application. More users felt Yelp Monocle was to create VGI than general user content. This was similar to results for OSM. Users did not feel Mixare was for user content or VGI. Users felt ARTags had more of a purpose to both user content and VGI creation than Layar.

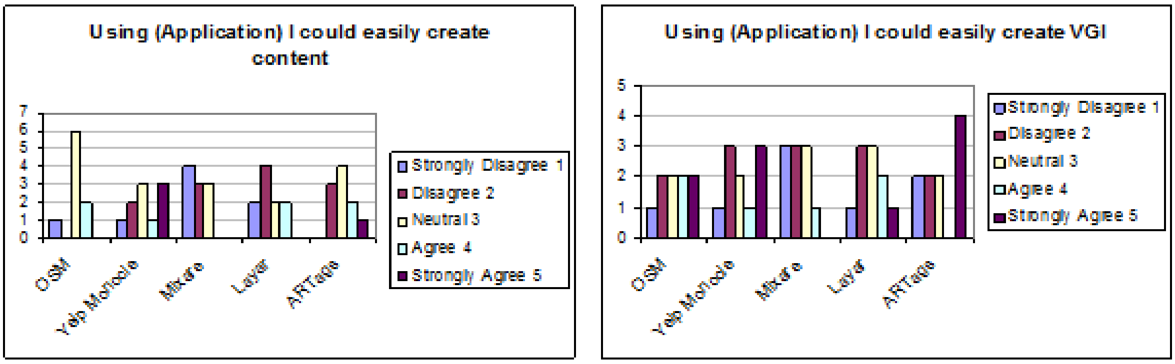


**Figure 4: Participant views on ease of content and VGI creation**

Participant views were split on whether they could "easily" create content and VGI using the applications. For both Mixare and Layar most participants did not feel they could easily create content. Layar had more participants than Mixare that felt it could be used to create VGI however. Again there were also differences between user perceptions of Layar and ARTags for both content creation and VGI creation.

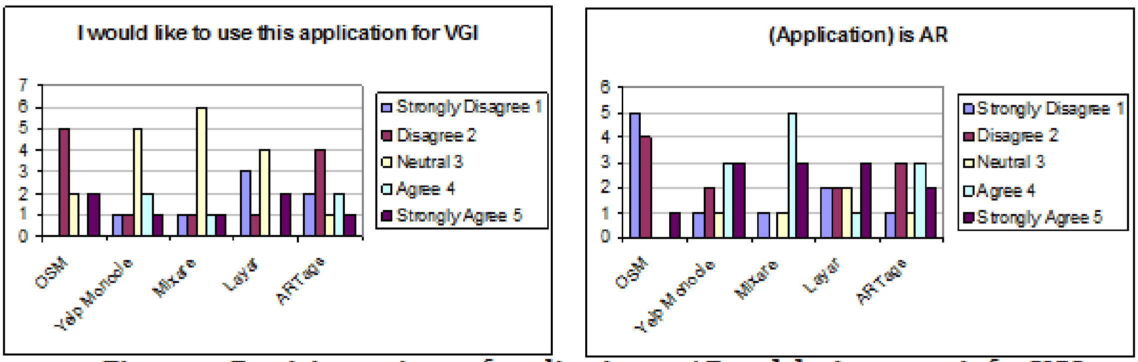


**Figure 5: Participant views of application as AR and desire to use it for VGI**

## Discussion

The main advantages of AR for enhancing VGI seem to be that it can allow users to interact in the real world 3d environment while contributing information. Unlike other VGI applications AR can allow users to create 3d objects in locations along with other information. These interactions do not only apply to virtual objects as users can annotate objects in the real world as well. This can potentially allow new forms of VGI but content creation in AR remains limited (Wither et al. 2009).

Examining existing AR applications showed that some allow forms of VGI but do not take advantage of their full potential. None of the applications took advantage of passive user contributions for enhancing geographic content. For some AR applications user geospatial content generation is only secondary. This is likely because a focus of many of the applications is on the presentation of content.

There are barriers that prevent common users from volunteering content. Many applications allow users access to free trials. However those that focus on 3d content generation don't always allow free trials or require technical expertise. While most applications include APIs that can be used to create new applications, there are still limitations on who can contribute data. Although advances have limited the extent to which geographic skills are required, they can be important for ensuring the quality of geographic data. Few of the applications tested showed actual mechanisms or procedures in place for verifying the accuracy of geospatial content contributed by users. This critique is typical for systems that allow VGI however (Jackson et al. 2013).

There are still limitations on AR content generation. A number of the applications tested only allow the offline generation of content. Those that allow online content generation are often limited to 2d content generation. Among those that allow 2d content generation only Mixare took advantage of existing VGI services such as OSM. While Yelp uses an existing service, the extent of user contributions is limited to user reviews and not the creation of geospatial content. The use of OSM in Mixare allows users to make geospatial edits. However using OSM in Mixare is more like opening up a separate 2d application instead of remaining immersed in the AR world.

Although the sample size from the pilot study is too small to make any generalizations, many participants of the pilot study seem to believe that AR applications offer some form of interaction that fits the definition of VGI. It is unclear however what specific aspects of the application make some user's feel this. Different aspects such as a clear ability to add online geographic content may influence users' perception. For instance there were clear differences between how users perceived ARTags and Layar. ARTags added the ability for users to clearly create online content in an AR application that relied on offline content generation. Yelp Monocle was often viewed as nearer to VGI than other applications with similar functionality. Both Yelp Monocle and Mixare allow user's to edit and add information about locations that already exist, but only Mixare allows location data to be added through OSM. Yet many users still view Monocle as more comparable to OSM in terms of VGI than Mixare.

## Conclusion and future work

Based on the review of existing applications AR commercial applications already seem to be integrating some aspects of VGI. While results of the pilot study suggest that users may perceive AR applications as VGI, more testing is needed to understand user perceptions of VGI in AR. There may be potential to further enhance VGI through AR by taking advantage of other aspects of VGI such as passive data. There is also a need to further include online 3d geographic content generation and tools that can allow online content generation.

Due to the need for user testing, usability and motivations for these applications was not explored. Future research will explore these aspects of VGI adoption in AR. The data provided is based on only a small number of observations. This study shows that the potential exists for AR VGI, but does not intend to draw any conclusions on whether these practices are widespread. There is also a need to examine more current applications to see what advances may be in use and where there is still a need for exploration.

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# Appendix A – Sample questionnaire

### Application 1 - Open Street Map

1. Definition: VGI or volunteered geographic information is geographic information acquired and made available to others through the voluntary activity of individuals or groups, with the intent of providing information about the geographic world.

| | | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|---|
| | **Question** | 1 | 2 | 3 | 4 | 5 |
| **1a** | Open Street Map uses VGI | | | | | |
| **1b** | With Open Street Map users can create VGI | | | | | |
| **1c** | I would like to use this application for VGI | | | | | |

2. Content creation.

| | | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|---|
| | **Question** | 1 | 2 | 3 | 4 | 5 |
| **2a** | The primary purpose of this application is to create user content | | | | | |
| **2b** | The primary purpose of this application is to create VGI | | | | | |
| **2c** | Using Open Street map I could easily create content | | | | | |
| **2d** | Using Open Street map I could easily create VGI | | | | | |

3. Definition: An AR or Augmented Reality system supplements the real world with virtual (computer-generated) objects that appear to coexist in the same space as the real world.

| | | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|---|
| | **Question** | 1 | 2 | 3 | 4 | 5 |
| **3a** | Open Street Map is AR | | | | | |