

DM4VGI: A template with dynamic metadata for documenting and validating the quality of Volunteered Geographic Information

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Abstract. Volunteered Geographic Information (VGI) is a Web phenomenon known as “user-generated content”, which involves resources from Web 2.0 and geographic data. Geobrowsers are websites that collect and provide VGI. These systems, however, do not follow norms or standards for data collection or documentation, which makes it difficult to recover such data and limits the interoperability among VGI systems. In addition, the quality of the data collected by VGI systems has often been questioned. This paper proposes the DM4VGI, a template for creating dynamic metadata from volunteered geographic information provided by users through Geobrowsers or Virtual Globes. The DM4VGI is used to document and validate the quality of the VGI, as well as to facilitate data interoperability.

1. Introduction

A Web phenomenon known as “user-generated content” is increasing and diversifying the creation of data in collaborative environments. Some examples of such phenomenon are the free encyclopedia - Wikipedia¹, the world maps voluntarily produced such as OpenStreetMap² and Wikimapia³, the information on public security available at Wikicrimes⁴, and several websites where clients are able to make comments about the quality of a product or service provided by a company.

The term Volunteered Geographic Information (VGI), defined by Goodchild (2007), characterizes a specific type of “user-generated content”, which combines three fundamental elements: Web 2.0 [O’Reilly, 2010]; collective intelligence [Lévy, 1999]; and neogeography [Turner, 2010].

A collaborative Web system is an environment where data are voluntarily contributed by the users, who can also discuss and assess the information provided by other users [Souza et al., 2012]. A Geobrowser is a type of collaborative system that enables the search, access, visualization and integration of geospatial data [Schrader-Patton et al., 2010]. According to Cooper et al. (2010) a Geobrowser that presents data in the form of a globe is called Virtual Globe (e.g.: Google Earth⁵). Websites such as

¹ <http://en.wikipedia.org/wiki/Wikipedia>

² <http://www.openstreetmap.org>

³ <http://wikimapia.org>

⁴ <http://www.wikicrimes.org/main.html>

⁵ <http://www.google.com/earth/index.html>

OpenStreetMap and Wikimapia are examples of collaborative Geobrowsers.

A common problem of collaborative Geobrowsers is that such systems do not usually follow norms or standards. Thus, the geographic information they collect and provide on the Internet are usually scattered and disconnected, hindering the interoperability of different systems. Even with the aid of the modern search engines available on the Web, locating and recovering information are difficult tasks since the VGI are usually created without any documentation/metadata [Cooper et al., 2010]. In order to achieve interoperability and reuse, the produced geographic data must have an associated metadata to facilitate the search and provide the necessary details for the proper use of such information.

The VGI can be dynamic, i.e., continually modified, but the user of a collaborative environment does not normally spend time or effort to fill out metadata forms. Thus, in order to document a collaborative web-based VGI System, it is necessary to automate metadata capture during the VGI data collection process and update the values of the metadata elements to reflect the dynamic changes in the VGI. According to Cooper et al. (2010), using dynamic metadata is required in order to document a VGI.

This paper proposes a template for the creation of dynamic metadata from information voluntarily provided by Geobrowsers, namely the Dynamic Metadata for VGI (DM4VGI). In this template, the metadata are dynamic because the values of their elements are collected and modified in real-time, in order to consider the possible changes in the VGI. The DM4VGI is used to document and allow other users to verify and certify the quality of the VGI.

The DM4VGI can be used by any collaborative Geobrowser and allows the metadata of the systems to be released and found by users or other software. The DM4VGI also enables the interoperability of data collected by several websites with different and dynamic content.

The structure of the paper is as follows: Section 2 presents a review of VGI and methods developed to improve its quality, in addition to a discussion on metadata and their importance. Section 3 describes in details the elements of the template proposed to document and verify the quality of the VGI from Geobrowsers, and justifies the choice of these elements. Section 4 describes the processes of creation and management of dynamic metadata. Section 5 presents the overall conclusions of the paper and recommendations for further research.

2. Volunteered Geographic Information (VGI)

According to Goodchild and Li (2012), the quality of the VGI can be highly variable and there is no method or procedure to completely assure its reliability. Because the VGI fails to follow the scientific principles of sample design and its coverage is incomplete with respect to the production of geographic data, its quality can be questioned.

However, this does not mean the VGI does not have its value. The VGI can be a generator of numerous scientific hypotheses, which can be validated using stricter methods [Goodchild and Li, 2012]. Important information can be more easily

discovered using VGI [Georgiadou et al., 2011 and Cooper et al., 2010]. For instance, a person who has lived in a given street for a long time is likely to have knowledge that can be shared with other people using the VGI. Thus, according to Goodchild and Li (2012), the development of methods to improve the quality of VGI may provide benefits to users VGI.

Many studies have proposed and evaluated methods that attempt to assure or improve the quality of the VGI [De Longueville et al., 2010; Cooper et al., 2011; Goodchild and Li, 2012]. The main methods proposed to verify if the VGI collection process is effective are: (1) to compare the VGI with other data sources; (2) to allow the users to grade and comment a VGI, thus making them responsible for its validation; (3) to make VGI available to data production specialists or official agencies, to be analyzed and validated by people with technical knowledge in a collaborative manner.

2.1. Methods to assess and improve the quality of the VGI

Comparing VGI with similar information from other official data sources is one method to assure its quality. For instance, the website Tracks4Africa⁶ receives volunteered information, which are often repeated, overlapping or similar, thus a comparison between data collected by the system with data from external sources is performed.

Cooper et al. (2011) suggests the importance of using tools that automatically correct the VGI, such as for logical consistency of a text. This type of tool may work as follows: it evaluates the information inserted by the user and, in case an invalid value is found, it requests the user to modify the contribution, pointing out the error as well as its location. These automatic correction mechanisms would be more helpful if used by several VGI Web providers, thus it is important to provide those tools in a web service format [Cooper et al., 2011].

According to De Longueville et al. (2010), another method to automatically assess the quality of the VGI is to use a zoom management system: when the user performs a voluntary contribution, the system registers the current zoom level of the map and associates it to the VGI. It is likely that the higher the zoom level at the moment of contribution, the higher the spatial accuracy of the VGI. As the zoom level increases, the system can automatically attribute a higher value to the metadata element related to accuracy. However, there are no guarantees that this method will always be successful: even though a user gives maximum zoom to provide a contribution, the process is still subject to errors, made either on purpose or by mistake [De Longueville et al., 2010].

According to Maué (2007), a reputation system similar to those seen in electronic commerce websites is important to help improve the quality of the VGI. In this method, the users of a VGI system can grade and comment on contributions provided by other volunteers, and thus co-validate or not the VGI. For instance, as the VGI receives positive feedbacks, its reliability is more likely to increase.

For Cooper et al. (2011), every volunteered information may have its quality assured by means of data review using Wiki services. Wikipedia is a successful example of good quality volunteered information, which the content is voluntarily provided and

⁶ <http://tracks4africa.co.za>

revised [Kittur, 2008 and Cooper et al., 2011]. Thus, data review performed by other users can be an important factor to encourage the contributor to follow certain norms and standards, as well as to provide metadata [Cooper et al., 2011].

Goodchild and Li (2012) proposed three different approaches as an attempt to assure the quality of the VGI. The first approach suggests a review of the VGI by other users under the philosophy that “the more the users visualize and revise the VGI, the more acceptable the information may become”, similarly to what happens with Wikipedia. The second approach suggests a reputation system that relies on a hierarchy of trusted users. For example, a user who more frequently makes positive contributions and reviews could be assigned a higher score, and be given a role as moderator or administrator of the system. The third approach suggests the use of methods for the automated triage system, to assess the credibility of the information using geographic theoretical concepts. The final score of the contribution can be calculated as the weighted average of the scores attributed by all users, considering that the scores from users in the higher levels of the hierarchy were given greater weights. The roles of the users may define permissions to remove illegal data, prevent or limit the editing of content which has already been corrected, or even ban malicious users, thus helping to control the system.

De Longueville et al. (2010), suggest the use of a list of predefined values from 0 to 5, in the “DropDown” or “ComboBox” format. Each of these values refers to a level of accuracy of the data, which is defined according to the creator of the content. Thus the higher the value selected by the user who produced the VGI, the higher the data accuracy. This value should be registered in the VGI metadata element related to its accuracy.

2.2. VGI metadata and documentation

Metadata are defined as “data about data”. Documentation of official data produced by agencies or organizations must follow international documentation standards. VGI should be documented as well, either manually or automatically.

According to Cooper et al. (2011), the VGI metadata must have elements that reflect its quality and the users experience in making use of such information. However, this is no guarantee against frauds or untruths in the metadata fields related to quality, since they are filled out by the contributor himself or automatically by tools based on concepts, which are not always true. This is a critical issue even for metadata generated by professional organizations or official agencies [Cooper et al., 2011].

An example of VGI metadata is seen in the GPS Traces of the OpenStreetMap, whose elements are: file name; date when information was sent; number of points collected; initial coordinate; owner; description; keywords and visibility. Another example is the The Southern African Bird Atlas Project 2⁷, whose elements are: observers, cards, records, incidentals and pentads. These metadata are related to all VGI collected in a given period of time, and not to a single VGI. This situation is similar for the Wikicrimes system metadata, which are number of registered crimes, number of occurrences and percentage of each type of occurrence per area.

⁷ <http://sabap2.adu.org.za/>

Fields for the control and analysis of changes in the VGI are also important. For example, the fields of the History Changeset⁸ of the OpenStreetMap systems identify the user who has modified a VGI, what item was altered and when the modification occurred. The OpenStreetMap is one of the few VGI systems that provide part of its data along with metadata. However, these metadata are standardized for only one specific type of contribution, such as the GPS Traces metadata. Ultimately, it is noticeable a total lack of standards for documenting the VGI, such as that existing for official geographic information. The following section presents an initial proposal of a standardized procedure for VGI documentation.

3. A template for VGI documentation

When analyzing or proposing a procedure for VGI documentation, there are two distinct paths to follow. One is the documentation of VGI from Geobrowsers and the other is the documentation of more complex and complete data, generated using software or Geographic Information System (GIS) tools, which can normally be available in a Spatial Data Infrastructure (SDI) [Cooper et al., 2011]. In this section we present the template Dynamic Metadata for VGI - DM4VGI, proposed to document VGI obtained from Geobrowsers.

According to Cooper et al. (2011), voluntary users do not usually consider spending additional time to document data, which they are already providing in a collaborative manner. Thus, the DM4VGI focus on the most relevant information about the data, in addition to being able to capture metadata automatically. Another interesting fact is that in several VGI systems, the information is not usually required to be exact. For example, the locations of a pothole in the street or occurrence of a robbery do not require high precision, i.e., the identification of a corner of such street or the block where the event was observed may be sufficient for decision makers who will respond to the VGI.

The DM4VGI was developed to achieve four objectives: to standardize and facilitate the documentation of the VGI; to provide statistical data with respect to the use of the VGI; to register data regarding VGI quality, captured through methods of VGI quality improvement; and to provide an efficient mechanism for VGI data search and access.

The template comprises 39 elements organized into five groups: Identification; Time Record; Geopositioning; VGI quality; and Auditing and Distribution. Figure 1 shows the structure of the DM4VGI and its communication with the collaborative environment through the VGI Documentation Module for data management communication.

Figure 2 shows the elements related to the data identification. Elements marked with '*' are mandatory. The elements Title (1.1) and Summary (1.2) are used to quickly identify the data, and they are present in several standards for data documentation. Two important elements to classify the contribution are Category (1.3) and Type (1.4), which are filled out through controlled vocabulary using "DropDown" or "ComboBox". These elements facilitate the search for similar information or of a specific theme, such as

⁸ <http://www.openstreetmap.org/history>

infrastructure, entertainment or public safety. They also enable a more detailed search such as for data regarding potholes in a street (“potholes in the street” could be a type of “infrastructure”) or streets with the greatest number of robberies (“robberies” could be a type of the category “public safety”). Thus the DM4VGI has the elements “category” and “type”, where type is always associated with only one category.

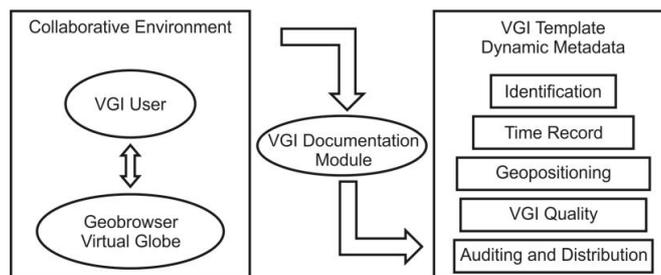


Figure 1. DM4VGI structure and communication with the collaborative environment through the VGI Documentation Module.

The DM4VGI aims to support the interoperability of data from several websites, thus two other additional elements were proposed: Software (1.5) - used in data collection (e.g.: Google Maps API⁹); and Website (1.6) - used in data collection (e.g.: Wikicrimes). This highlights the needs for auditing the VGI collection, documenting the tools used in this process as well as the organizations or websites responsible for it.

	Element	Item	Type	Auto captured
Identification	Title*	1.1	Text	X
	Abstract	1.2	Text	
	Category*	1.3	String (controlled vocabulary)	X
	Type*	1.4	String (controlled vocabulary)	X
	Software*	1.5	Text	X
	Website*	1.6	URI	X

Figure 2. DM4VGI Template – Identification Group

Figure 3 shows the fields related to the time record of the data. The relevant elements for a complete temporal search are: Date and Time of the Contribution (2.1); Date and Time of Occurrence (2.2); and Date and Time of Updates (2.3). Date and time of the contribution means the moment when the contribution was performed. Date and time of occurrence means the moment when the fact or event occurred, and not the moment it was recorded. For example, the user inserts a robbery record into the system three days after its actual occurrence date, or the user registers an event that will take place one week after the contribution date. Date and time of updates contain a list of dates and times when changes in the VGI were performed. If the system allows Wiki reviews, the VGI can be modified several times, and every change must be recorded and maintained for future analysis.

Figure 4 shows the mandatory elements related to data positioning. The VGI should be documented in a way so that it enables the spatial search of the metadata.

⁹ <https://developers.google.com/maps/documentation/javascript/>

Thus it is necessary to maintain the data's bounding rectangle (elements 3.1 to 3.4). The element Geometry (3.5) registers the type of the VGI geometry: point; line; or polygon.

	Element	Item	Type	Auto captured
Time Record	Date and Time of the Contribution*	2.1	Timestamp	X
	Date and Time of Occurrence	2.2	Timestamp	X
	Date and Time of Updates*	2.3	Array Timestamp	X

Figure 3. DM4VGI Template – Time Record

	Element	Item	Type	Auto captured	
Geopositioning	Bounding Rectangle	North*	3.1	Float	X
		South*	3.2	Float	X
		East*	3.3	Float	X
		West*	3.4	Float	X
	Geometry*	3.5	String	X	

Figure 4. DM4VGI Template – Geopositioning

Figure 5 shows the elements related to the Statistics and Quality of the VGI. The element User's History (4.1) registers the personal comments made by a user who has downloaded, used, or has relevant information about the VGI. This element was included in the DM4VGI due to the advantage of maintaining post-use data, for instance, the post-use information of an Ebay¹⁰ product, as well as the collaborative forum of the systems Wikicrimes, VGIPantanal [Souza et al., 2012] and MossoroCrimes [Vidal Filho et al., 2013].

The collaborative forum of the Wikicrimes and MossoróCrimes systems can be defined as the fields where the user can give opinions and comment on the contributions, with the intention of helping in the process of validation or showing its errors or untruths. Thus the VGI users provide a wide range of information, characteristics and consequences of the post-use of the VGI, which can also be considered as tools for the VGI quality assessment. The users can use such collaborative information as basis to identify if the VGI is true or false.

The element Number of Visualizations (4.2) is used to register the number of times the contribution has been visualized, allowing the identification of the most accessed contributions.

The first approach described by Goodchild (2012) suggests a Wiki review of volunteered data. Therefore, it is important to register in the metadata the number of Wiki reviews performed, and obtain an estimate of how much such contribution has been improved or extended. Such record makes it possible to assess the impact of Wiki reviews on the VGI in a quantitative manner. The element Number of Wiki Reviews (4.3.1) registers the number of Wiki reviews who revised a VGI. The element Number of Wiki Users (4.3.2) registers the number of different users who revised a VGI.

The element Contribution History (4.4) registers a list with a unique identifier for old contributions in order to keep a history of volunteered information and, if necessary, to enable going back to a previous state of the VGI. For instance, if a user modifies the VGI and someone or some automated data correction method identifies

¹⁰ <http://www.ebay.com/>

that the status of the VGI was altered from “correct” to “incorrect”, it is necessary to return it to its previous state.

	Element	Item	Type	Auto captured	
VGI Quality	User’s History	4.1	Array Text		
	Number of Visualizations*	4.2	Int	X	
	Number of Wiki	Reviews*	4.3.1	Int	X
		Users*	4.3.2	Int	X
	Contribution History	4.4	Array Int	X	
	Number of Evaluations*	4.5	Int	X	
	Score	Final Score*	4.6	Float	X
		Minimum Value*	4.6.1	Float	X
		Maximum Value*	4.6.2	Float	X
	Status*	4.7	String	X	
	Assessment Method	4.8	Text	X	
	Zoom Contribution*	4.9	Text	X	
	Zoom Wiki	4.10	Array Text	X	

Figure 5. DM4VGI Template – VGI Quality

According to De Longueville et al. (2010), the contributor can provide a personal score about the accuracy or quality of his own data at the moment of the contribution. Thus the DM4VGI has fields to identify the reputation of the VGI considering, for instance, the scores provided by the users. It is important to mention that all users should be allowed to grade all contributions, in order to avoid taking into account only the opinion of the one who produced the data. The final score of a VGI could be calculated as the weighted average of all scores it received. In order to do so, the element Number of Evaluations (4.5) is necessary, since this field registers how many distinct users graded the contribution.

The users’ ranking should be used, as discussed by the second approach of Goodchild (2012), which shows the importance of the hierarchy in collaborative systems. In order to calculate the final score of the contribution, the system calculates the weighted average considering the users’ ranking, which is then registered in the element Final Score (4.6) of the DM4VGI. The elements Minimum Value (4.6.1) and Maximum Value (4.6.2) register the possible limits for the field Final Score.

Keeping the users’ ranking is a method to help the VGI quality validation. Users who participate in a positive and constant manner should be in higher levels in the hierarchy compared with those who constantly provide erroneous contributions or untruths. A user who provides malicious, unethical or criminal contributions should be in the lowest levels and could be banned from the system. The higher the hierarchy level or position of the user grading the VGI, the greater the weight of this score in the calculus of the VGI’s final score. This final score should be a weighted average considering the user’s level.

The element Status (4.7) consists of keeping a record of the status of validation or judgment on the quality of the VGI, for instance, if it is still being evaluated or has already been validated by website administrators, organizations, or the users. Thus the status of the VGI can be: “Under evaluation”, “Approved”, and “Reproved”.

The element Assessment Method (4.8) registers a description of the method used to assess the VGI (e.g., comparison of the VGI with other data sources, user’s scores

and assessments, or the combination of one or more techniques) and who are the responsible for its final validation (e.g., website administrators, agencies or organizations, or the VGI users).

The DM4VGI is based on the suggestion by De Longueville et al. (2010) about zoom management, with an additional feature. The element Zoom Contribution (4.9) registers the zoom level of the map during the contribution. In addition, the system also captures the map zoom level at each Wiki review with the element Zoom Wiki (4.10). The zoom level can be captured automatically by some API method or function, such as the Google Maps API.

Documentation standards for geographic metadata have fields to identify those responsible for the production, update and distribution of the data along with their metadata (e.g., ISO 19115 and CSDGM). Therefore, the auditing and distribution of information should also be documented in the VGI metadata. Figure 6 shows the elements related to the auditing and distribution of the VGI. The VGI can contain several authors and editors, some even anonymous. Thus the identification element of an author should be a users' list. An "anonymous user" could be one value of the element "Name". The element Ranking (5.4) registers the name of the ranking system used, the Ranking Position (5.5) keeps its hierarchical level and the Ranking Scale (5.6) registers the hierarchical levels of the VGI ranking system.

	Element	Item	Type	Auto captured	
Auditing and Distribution	Array VGI Author	Name*	5.1	String	X
		Age Group	5.2	String	X
		Email	5.3	String	X
		Ranking	5.4	Text	X
		Ranking Position	5.5	Text	X
		Ranking Scale	5.6	Text	X
		Internet Protocol*	5.7	String	X
	Array VGI Distributor	Name*	5.8	String	X
		Email*	5.9	Text	X
		Website	5.10	URI	X
		Internet Protocol*	5.11	String	X
	Link to Download or Access*		5.12	URI	X

Figure 6. DM4VGI Template – Auditing and Distribution

4. Use of dynamic metadata in the VGI Template

The processes of production and update of the metadata elements should start with data collection and continue until the last modification and/or access to the VGI. This requires a Geobrowser, a complete collaborative environment, and a VGI Documentation Module to control and monitor the users actions within the VGI system.

Metadata do not necessarily have to be provided by the user who produced the VGI. Most of the DM4VGI elements are automatically created during the processes of VGI collection and edition. Afterwards, in case of a missing metadata element, the contributor or any other user can complete the metadata in a collaborative and cooperative manner.

Figure 7 shows a suggestion of architecture for the VGI documentation in Geobrowser. The user can dynamically interact with the Geobrowser, being able to

create, edit or evaluate the data. If the user provides a new VGI, the VGI Documentation Module is responsible for the capture and generation of all necessary information registered by the user during the contribution, automatically creating most of the metadata fields. Afterwards, the contributor is required to inform the additional fields that were not filled out by the VGI Documentation Module. It is important to highlight that such step can be performed any time and by users other than the contributor.

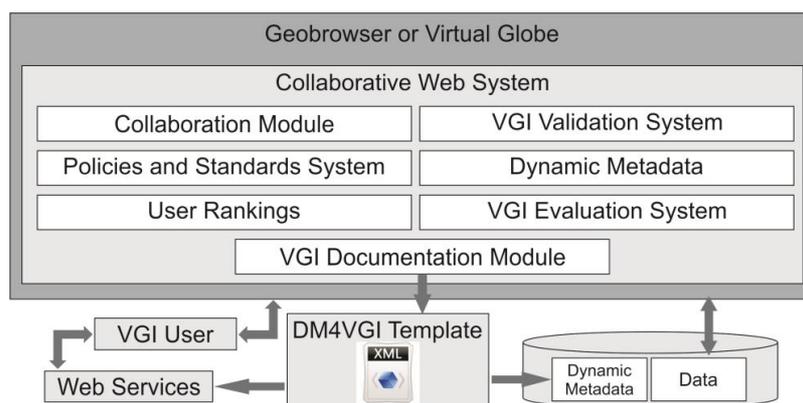


Figure 7. Architecture for VGI documentation in Geobrowser

If the user modifies an existing VGI, the VGI Documentation Module must recover the metadata related to the modified VGI, and then update or complete the necessary fields. The modifications must be done so that the metadata is compatible with the new status of the data.

The VGI Documentation Module is also responsible for saving and updating the dynamic metadata in the database, but the data are responsibility of the Geobrowser or another layer of the collaborative Web system. The web service layer is responsible for the publication of these metadata so that search mechanisms and metadata catalogs can find such information. Thus a collaborative Web system using the DM4VGI together with the proposed VGI architecture can provide greater visibility to its data and system, since other systems can have access to these metadata and the VGI and/or website that collected it.

Figure 8 shows the following quantitative comparisons: total number of elements of the DM4VGI; total number of elements automatically captured; number of mandatory elements in the DM4VGI; number of mandatory elements automatically captured; number of optional elements in the DM4VGI; number of optional elements automatically captured. It can be observed in Figure 8 that almost all elements are automatically captured, provided that this information is available in the VGI. Thus, it is possible to document the VGI with little or no demand for time and effort of the contributor. Afterwards, the elements which were not automatically filled out can be completed by other users or system administrators. A good human-computer interface can induce the user to provide part of the metadata naturally and complementary to the VGI.

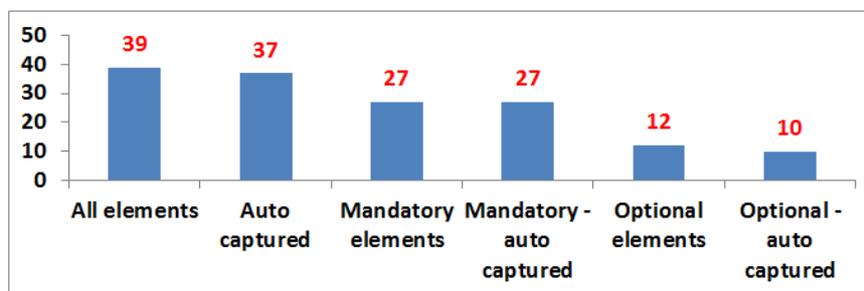


Figure 8. Number of elements of the DM4VGI

5. Conclusions

This paper proposed the DM4VGI, a template for the documentation of Volunteered Geographic Information from Geobrowsers or Virtual Globes systems. In addition to presenting auditing, descriptive and temporal information, the template also provides statistical data with respect to the use and quality of the VGI. The VGI users themselves play the role of reviewers of data and metadata, which makes documentation a completely dynamic process. In an environment where the data are dynamic, i.e., the VGI can be modified anytime by the users, the metadata should be updated as well, to guarantee coherence of the VGI documentation. Therefore, it is necessary to collect metadata in a dynamic manner to document the VGI.

This paper proposed the automatic retrieval of metadata to document a VGI using collaborative environments such as Geobrowser or Virtual Globes. Also, the paper suggested a VGI Documentation Module to control and update metadata in such environments. Since most of the metadata elements are automatically captured or calculated, the additional effort and time spent in VGI documentation are minimum.

Considering the VGI metadata database, a series of analyses about the volunteered data captured by the DM4VGI can be performed. For instance, we can obtain responses for the following questions: Which VGI had the greatest number of Wiki reviews or was more visualized? Which are the VGI of a certain type or category? What is the quality of the VGI according to its users? Has any user ever used the VGI? Has this user approved the VGI? What are the users involved and responsible for the production, update and distribution of the VGI?

The VGI metadata can be published in a system similar to the metadata catalog of an SDI. Thus the VGI can be more quickly and easily found and analyzed by humans and machines. The search and data analysis of several Geobrowsers or Virtual Globes can be integrated with many types of geographic data. Supporting the interoperability of the VGI allows the comparison of data from different systems, for instance, the crime rate of two cities that have their own collaborative system.

The DM4VGI has useful elements to aid in the process of validating the quality of the VGI. The good quality of the data provides more credibility to a collaborative system, whereas low quality data can lead the system to a complete discredit. The DM4VGI is being used in the collaborative environment CidadãoViçosa, available at <<http://www.ide.ufv.br/cidadaovicosa>>.

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