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Democratization of mapping: Conceptual design and implementation of a multi-channel, multi-purpose participatory mapping program

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Abstract

Volunteered Geographic Information (VGI) enables a form of participatory mapping that, relying on the Internet technology, allows communities to get involved in mapping projects. Unfortunately, due to the lack of Internet access especially in developing countries, this approach is not everywhere accessible. Ushahidi, one of the leading developers in this field, provides a solution to support the collection of VGI. However, this solution has several weaknesses, including the slow processing of information and the missed opportunity to enable collaboration between contributors. The concept implemented in this study overcomes these weaknesses and conceptualizes, implements and publicly evaluates a participatory mapping platform incorporating a new concept of Volunteered Geographic Services (VGS) and automatizing the processing of information. Its main component is a versatile Android application, which allows users to provide spatial participatory information via Internet and, more importantly, using the Short Message Service (SMS) approach. The final platform is usable worldwide and for different use cases. Particularly, it enables a user-friendly collaboration between participants of different origins, social statuses and degrees of expertise.

Keywords: Participatory Mapping, Volunteered Geographic Information, Volunteered Geographic Services, Ushahidi, Web GIS, SMS, Disaster Management

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1 Introduction

The term "Participatory Mapping" was introduced in the 1970s as one of the methods that aimed to *"enable rural people to share, enhance, and analyze their knowledge of life and conditions, to plan and to act"* in the process of creating maps together (Chambers, 1994, Guldi, 2017). Participatory Mapping is used in order to bring people together and visualize their living space and discover and solve conflicts, by letting the participants create a map using drawings, paper sheets and other cartographical techniques. Nearly 40 years later, enabled through GNSS and the Internet, a new form a participatory mapping called Volunteered Geographic Information (VGI) and Participatory GIS emerged (Goodchild, 2007, Forrester and Cinderby, 2011). While the original method of participatory mapping was practised in a group with people working together face to face, VGI is voluntarily created geographic information by anonymous citizens for a certain purpose, *"essentially the production of spatial information for society by society"* (Ho and Rajabifard, 2010).

The big benefit of VGI is that it can be created rapidly and at no charge, since anyone equipped with a smartphone can create geographical information and act as a "sensor". A network of such human "sensors" can create a vast stream of up-to-date geospatial information. Such networks can fill gaps in information that are usually not covered in traditional maps, i.e. data that cannot be collected because the traditional gathering approaches would be too time consuming and expensive, or because certain information can only be collected by locals (Ho and Rajabifard, 2010, Tampubolon, 2020).

VGI data has a wide spectrum, which ranges from snow quality on ski hills, bird species, tracking of bike and hiking routes, to maps of criminal violations and vulnerability (Castelein et al., 2010, Savelyev et al., 2011, UN-Habitat, 2020). The range of VGI makes it useful for different kind

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of approaches, ranging from mapping up to scientific data collection. However, there are also concerns about using VGI for certain purposes (Haklay, 2010, Senaratne et al., 2016, Antoniou and Skopeliti, 2015), such as variations in the quality, but nonetheless the potential usefulness of VGI to society is enormous.

1.1 VGI for Disaster Management: The example of Ushahidi

This potential can be best demonstrated by looking at the field of disaster management and the use of the VGI platform Ushahidi after the devastating earthquake in Haiti 2010. This platform was implemented to support the collection and management of geospatial data in the context of disasters (Duc et al., 2014) and has been used since 2010 in various crises, since it provides a solution to *"aggregate, correlate, and present information in a manner useful to rescue services"* (Thatcher, 2013).

The unique approach of Ushahidi was to create a mashup between browser-based mapping application and the SMS text messaging technology (McNamara, 2015). Especially in a crisis or in low income countries the access to the Internet can be limited or is not possible (Schachenhofer et al., 2023) and therefore allowing the user to submit information through SMS is significant. After or during a natural disaster one essential problem that responders face is the lack of real-time data that would help to get an overview on the current situation (Hein et al., 2017). The users of the Ushahidi-platform in Haiti were able to deliver relevant VGI by submitting reports using web application, a mobile client or via SMS. By collecting, filtering, translating and ordering such Information, the volunteering supporters were able to significantly help rescue services, nongovernmental organisations (NGOs) and other organizations to create a "live map" on the crisis and coordinate aid measures appropriately.

Despite the success, the Ushahidi-team also faced some difficulties due to the workflow of processing the emergency reports. The platform received between 1000 and 2000 SMS-reports per day, which summed up to 30,000 SMS-reports in the first month after the earthquake (Mora, 2011). Through the analysis of the workflow that the reports underwent, the following weaknesses in this process can be identified:

- Reports received via SMS have to be reviewed and geotagged manually.
- The absence of accents, the use of shorthand notations, and other grammatical inaccuracies significantly hinder the accurate translation and automated processing of reports.
- Volunteers handling the messages are restricted to providing information, comfort, or encouragement, without the ability to offer practical assistance

The first two weaknesses can be categorized as technical issues; the last issue seems to be a conceptual problem that has to be solved.

Even when Thatcher (2013) states that *"the inspiration for [Volunteered Geographic Services (VGS)] lies in VGI's usage in crisis response and management"*, neither she nor Savelyev et al. (2011) are considering a key impediment of VGI in developing countries: the access to Internet and the complexity of technology (Kyem and Saku, 2009) The latest report of the Broadband Commission for Digital Development (ITU and UNESCO, 2024) shows that the proportion of households with Internet access is, for example, in Africa around 37% and in Asia-Pacific below 66%, compared to Europe where it is 91%.[1] These numbers illustrate the digital divide. i.e., the gap between those parts of the world where access to information and communication technology is significantly different: Parts of the global population still are not connected via Internet and can neither get nor share information in case of a disaster. NGOs, scientists, and developers and developments have to consider this in their work.

1.2 Concept of Volunteered Geographic Services (VGS)

One of the identified limitations of VGI, which was stated first by Savelyev et al. (2011) and Thatcher (2013), and were pointed out above, is that VGI-projects are focusing on collection of information, but are missing the option of VGI to trigger action, as well as to integrate contributors of information into decision-making. The concept of Volunteered Geographic Services (VGS) is proposed as a solution to *"to develop an infrastructure to contribute and exchange micro-services"* (Savelyev et al., 2011) and to *"collapse the conceptual distance between information representation and action"* (Thatcher, 2013). This concept criticizes that volunteers are limited to the task of information provision but are excluded from acting. The provided information is used in the decision-making process, which, however, is not performed through the VGI-platform, but by authoritative parties (Thatcher, 2013). The goal of VGS is to move the idea of VGI even further by turning the information into action (Savelyev et al., 2011, Thatcher, 2013). The help provided goes beyond digital services as categorized by Sha et al. (2025).

Generally speaking: A platform implementing VGS-concepts will allow the users not only to submit information, but also offer services and consume services offered by other users in advance or spontaneously, in the case of spontaneous volunteers (SVs). For example, in case of evacuations, VGS would offer each citizen the possibility to announce the availability of seats in his/her car, as well as to ask for available transportation in his/her vicinity. Experiences from diverse crisis situations show that SVs can be willing to assist in vast numbers (Bier et al., 2025).

1.3 Alternative approaches

The responses to flood disaster in Germany 2021 (BMI, 2022, Bier et al., 2025) and Spain 2024 (EFE, 2024) prove that large number of spontaneous volunteers (SVs) can be

[1] This is a significant progress compared to previous years. In 2015, in Africa around 10.7% and in Asia below 39% used the Internet, compared to Europe where it was 82.1% (ITU and UNESCO, 2015).

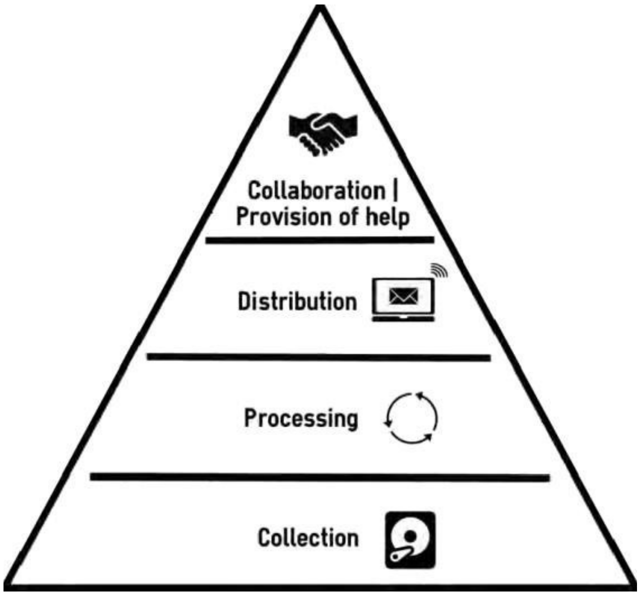

Fig. 1. Workflow of the information leading to collaboration.

motivated to provide support in disaster situations. Web-based platforms can support the commitment (BMI, 2022, p. 22), but do not use any spatial data. As Bier et al. (2025) show their satisfaction with authorities increases significantly if collaboration with disaster relief organisations is possible. However, "there are no established channels of communication and collaboration", as the authors state. Social media were found to be important message channels.

Comparable approaches to collect geospatial data are ODK[2] and its fork ODK-X[3] with ODK-X Survey[4]Accessed: 29.03.2025], applications with focus on data collection. Locational information, form-based data, and images can be collected, based on configurable forms and transferred online (synchronized or unsynchronized) to a server. However, the mutual communication and service approach is not supported.

2 Objectives

The motivation of this study and development is not only to improve the workflow of tools like Ushahidi, but to conceptualize and implement a platform that incorporates the concept of VGS and in consequence triggers activism among the users of the platform. To trigger actions, the concept of VGS will be extended to link users with compatible requests and offers, within a certain geospatial distance, following the concepts of semantic similarity and positional nearness (Poorazizi et al., 2015). Requests and reports are generated in a systematic manner, allowing automating processing without human intervention: Neither manual geotagging nor translations of reports are required. Individual mental stress (Munro, 2013, Bier et al., 2025) of digital volunteers can be avoided. The prototype will not depend on Internet availability, i.e., it can be used in areas without Internet access, and is adaptable for different purposes using a thesaurus, that delivers the user only a limited selection of terms that can be interpreted and matched automatically.

3 Implementation

3.1 The concept

The working principle of the prototype platform is based on the way in which Ushahidi collects VGI for crisis management. The key improvements are, on the one hand, that the processing of the information is more automated and, on the other hand, that it implements the concepts of VGS.

As shown in Fig. 1, the process begins with the collection of information from different sources, then the information is processed automatically or with human support by filtering and selection of useful information. The next step is the distribution of information.

The distribution plays a significant role in triggering collaboration and can happen indirectly or directly. Indirect distribution means that the information is not forwarded to a specific person or organization, but is accessible by all users. The positional information and the request can be distributed using an email broadcast and/or can help rescue services and other users by creating a live map of the situation. Direct distribution means that relevant information is forwarded directly to a person or organization because request and service offered resp. common interest or location match each other. For example, this can be the location of a damaged street, forwarded to the municipality, or a request for water forwarded to an NGO.

After installation of the app and registration (see first screen in Fig. 4) the user can ask for resources, such as commodities, tools or services in a three-step process. After each selection, the items in the list become more precise. The underlying thesaurus can be customized and extended, making the platform adaptable for different purposes, i.e.

[2]https://getodk.org/ [Accessed: 23.01.2025]
[3]https://odk-x.org/ [Accessed: 23.01.2025]
[4]https://github.com/odk-x/survey/releases [

Initialization	Selection of category	Final issue
Mark a point in the map	Violence	Road damage
Ask for help	Nature events	Broken light
Provide help	**Damages**	**Illegal Waste Disposal**
	Civil movement	
	Miscellaneous	

Fig. 2. Sample process: Selections to be made in order to report an illegal waste disposal.

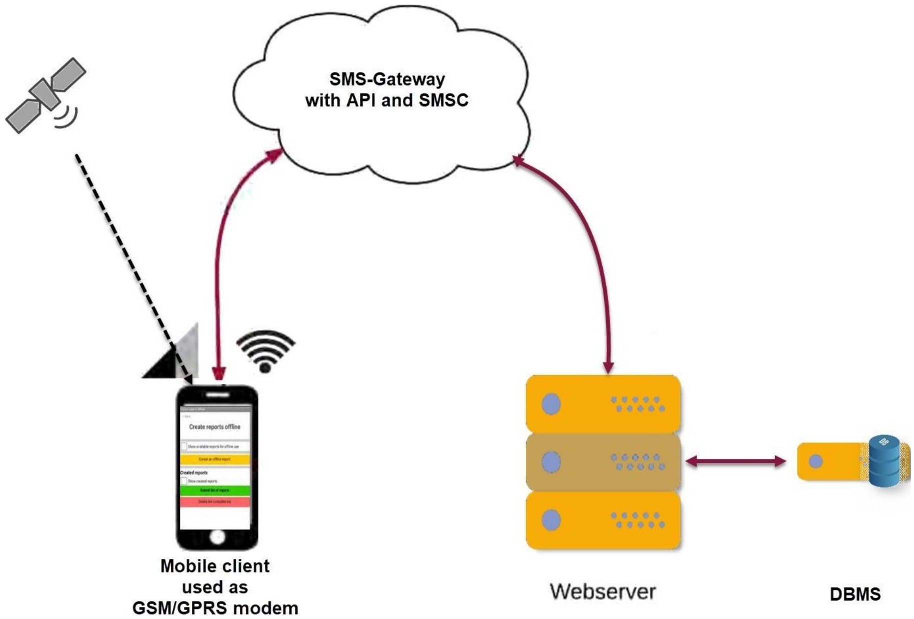

Fig. 3. Communication flow when creating and submitting a report using SMS.

participatory mapping, disaster management, citizen science, or neighbourly help.[5]

In the first step, as depicted in Fig. 2, the user has the possibility to choose if his information will be distributed indirectly ("Mark a point in the map") or directly ("Ask for help/Provide help"). In the next step he can describe his concern more precisely before submitting the final request where the geographical location is included automatically.

The spatial location in combination with the selected items is transferred to a server and saved in a database. A search for users who are able to provide concrete and physical help can be performed. After an appropriate user is found, the platform provides both users the location and contact information, so they can establish contact and possibly help each other ("Collaboration/Provision of help" in Fig. 1).

All submitted reports are visualized on a map with markers. Reports in which a user asks for help or is volunteering to provide help are processed further. To cite an example, if someone requests an electricity generator (Ask for help > Equipment > Electricity generator), the database will be consequently searched for such an item (Provide help > Equipment > Electricity generator) which was offered before.

The submitter of the report who triggered the search and the submitter of a reply or offer are informed about the successful match, and they can establish contact and possibly support each other.

Depending on how the person who submitted the report – via the Internet or a Short Message Service (SMS) – the platform responds in the same mode. It is up to the users to react to this message and to contact each other via phone call, SMS, or e-mail. Additionally, rescue services in a certain radius can contact users of the platform. Request can be stored offline and processed when connectivity via cellular network or Internet is available.

[5]The list can be setup based on experiences in previous crisis situations. After the earthquake in Haiti in 2010, affected people required information about items like local schools, water distribution and quality, availability of gasoline or diesel in gas stations, open pharmacies, supermarket hours, sewage collection tanks, recovery assistance centers, ATMs, location of Wi- Fi hot spots (Mora, 2011). Munro (2012) provides a dataset with 25,000 message at `https://github.com/rmunro/disaster_response_messages`.

Fig. 4. User interface structure of the app.

3.2 The technical implementation

In order to deal with all communication options – and their limitations – three approaches are developed and implemented to support this multi-channel, multi-purpose VGS approach (see "Main Screen" in Fig. 4):

1. If Internet is available, a browser-based app can be used.
2. If Internet is not accessible, SMS-based communication will be used. SMS can be widely used in development context (Delattre, 2015), i.e., for medical purposes (Apunyu and Hoefman, 2010) and in agriculture (Sharma et al., 2021, Olwalo, 2023). This approach is explained in detail in the next paragraph.
3. In the event that there is no connectivity at all — i.e. in the event of a complete radio blackout or if the network infrastructure is overloaded – messages can be recorded offline and temporarily stored in the smartphone. The stored messages are transmitted as soon as connectivity is available again.

The device mainly used is the mobile phone which acts as an endpoint to the regular cellphone network. Here the main component is a versatile Android application that allows users to provide spatial participatory information via Internet and, more important, SMS. Since a text message cannot be transferred directly to a webserver because of different protocols (HTTP vs. SMS), additional components are needed in the SMS case in order to transmit it, and a different workflow of processing the message content on the server (Fig. 3). The main component needed for this purpose is an SMS-Gateway which allows bi-directional communication to a Short Message Service Center (SMSC). This gateway can forward the content of the messages received via HTTP to any accessible network node or to another SMS client offering its HTTP-based API.

In the prototype, the SMS-Gateway was implemented by using FrontlineSMS[6] that can turn any mobile phone into a SMS-Gateway to forward the message to any web server identified by its URL. Alternatively, Ushahidi's SMSsync gateway could be used. The text message automatically includes the position of the user without substantial differences in content to a report submitted directly over the internet. On the server the match of requests and offers for help is performed. The potential partners are informed.

3.3 User interface design

The app comprises a number of screens, partially shown in Fig. 4. Design criteria are being developed to ensure that the app can be used safely and efficiently even in crisis situations (Borchers, 2021, Tan et al., 2020):

- Clarity: The user should not take more than ten seconds to deduce its basic function and how to achieve them.
- Efficiency: Every function of the app should be accessible in three motions/clicks.
- Usability: Cluttered interfaces are avoided. Large icons and buttons favour usability in crisis situation.
- Feedback: The user should know when the execution of a function was successful or failed.
- Simplicity: It is better to limit the number of features than overload the user with available options.

3.4 Public Testing

A public testing phase evaluated the mobile client's functionality and user-friendliness through Google Play Store distribution. The app included position simulation for indoor testing convenience. Survey results showed strong interest, with 81% of respondents willing to request help and 93% willing to provide assistance using the app. User-friendliness ratings were positive, with 55% rating it "very high" and 45% "medium."

The thesaurus approach effectively minimized message creation effort, particularly valuable in emergencies. However, users found predefined entries restrictive, suggesting the addition of free text fields supported by Natural Language Processing enabling *"swift and effective response"* (Munro, 2012, Otal and Canbaz, 2024).

4 Discussion and Evaluation

4.1 Achievement of the Objectives

The functionality provided by the platform can cover a range of applications, which was proven with the use case based assessment. The platform is able to link users with compatible requests and offers within a certain radius.

The mobile client provides the option to submit reports and receive response via SMS, Internet, or even with delayed transfer while in offline-mode. The matching of the submitted reports is fully automated, furthermore, no manual geotagging of the reports is required. If necessary, the received reports can be automatically forwarded to a suitable organization depending on the term. The user-friendliness of the platform is rated as high, which was achieved through the implementation of the thesaurus, automatic position derivation and a simple GUI of the Android application.

4.2 Conclusion

To achieve the main objectives, it was required to implement a participatory mapping platform that is operational in areas without Internet connection, refusing to marginalize a big share of the population. In addition, the final platform does not simply collect VGI, but is able to trigger collaboration among users.

The developed concept and working principle behind the implemented platform is characterized by two innovations: the thesaurus approach and the incorporation of the VGS concept. The thesaurus approach brings many advantages in the realm of participatory mapping with nonexperts as main contributors. It facilitates the report submission, increases the user-friendliness and makes the platform adaptable to a wide range of purposes. Apart from it, the most significant benefit of using this approach is that it allows the automation of report processing. However, this approach limits the user and the variance of reports, since the message content has to be chosen from the existing thesaurus. Nevertheless, this negative point can be mitigated by extending the user interface.

The successful incorporation of the VGS concept shows that the purpose of a participatory mapping platform can go beyond collection and visualization of geographical information to become a source of collaboration. The successful incorporation of the VGS concept illustrates that participatory mapping platforms can serve not just to collect and visualize geographic information, but also to foster collaboration.

In the context of disaster scenarios such as earthquakes, the significance of this approach becomes evident, as it can alleviate operational pressures on humanitarian organizations and accelerate the delivery of humanitarian assistance by volunteers or aid organizations. A-posteriori reviewing and geotagging, leading to intensive manual work, can be avoided.

[6] https://www.frontlinesms.com/ [Accessed: 05.03.2025]

The challenge of bundling the innovations into a platform that can also be used without an internet connection was achieved by providing the user with a mobile client that enables participation via SMS with the same functions as when using a web browser with an existing HTTP connection. In addition, the application supports the offline collection of VGI even in areas without any network connectivity. However, for the installation Internet access is needed.

The final platform is an example of how participatory mapping can be made accessible and help communities all over the globe. Even though the implemented platform is a fully functional product, it must be taken into account that it is a prototype: Improvements and further research to be made in order for it to be ready-to-release.

Taking all these aspects into account, the present work can be seen as a step forward in the democratization of mapping. The technologies used do not place any great demands on the server location. As an open source-based solution, there are no licence costs (with the exception of telecommunication fees, such as for SMS messages). Data and the innovative approach remain in the regional context, so that data colonialism is avoided. The technologies employed do not impose significant requirements on server infrastructure. As an open-source solution, no licensing costs occur. Both the data and the innovative approach remain rooted in the regional context, thereby preventing data colonialism (Kuk, 2016, Madianou, 2019). *"Technology that is too complex or expensive for general use"* (Mora, 2011) is avoided.

Due to the scope of this work, the value of the VGS concept was deliberately not comprehensively determined, as the focus was on the technical implementation. Nevertheless, this work shows how this concept can be used to reward an altruistic behavior and enable contributors to mutually help one another. Also Mark Boyle (Boyle, 2015) describes what a powerful and essential resource human collaboration is. After an experiment during which he lived completely without money for one year, only relying on help from other people and small number of possessions, his conclusion was: *"More than anything else, I discovered that my security no longer lay in my bank account, but in the strength of my relationships with the people, plants and animals around me."* (Boyle, 2015). The motivation of helpers and their willingness to go to great lengths is proven in many emergency situations.

Conflict of Interest

The authors declare no conflict of interest.

CRediT Statement

GD: Conceptualization, Investigation, Methodology, Formal analysis, Writing – original draft. FJB: Conceptualization, Supervision, Project Administration, Writing – review & editing.

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