Towards a Usability Scale for Participatory GIS

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Abstract Since its emergence in the 1990s, the area of Participatory GIS (PGIS) has generated numerous interactive mapping tools to support complex planning processes. The need to involve non-expert users makes the usability of these tools a crucial aspect that contributes to their success or failure. While many approaches and procedures have been proposed to assess usability in general, to date there is no standardized way to measure the overall usability of a PGIS. For this purpose, we introduce the Participatory GIS Usability Scale (PGUS), a questionnaire to evaluate the usability of a PGIS along five dimensions (user interface, spatial interface, learnability, effectiveness, and communication). The questionnaire was developed in collaboration with the user community of SeaSketch, a web-based platform for marine spatial planning. PGUS quantifies the subjective perception of usability on a scale between 0 and 100, facilitating the rapid evaluation and comparison between PGIS. As a case study, the PGUS was used to collect feedback from 175 SeaSketch users, highlighting the usability strengths and weaknesses of the platform.

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1 Introduction

The term Participatory GIS (PGIS) refers to the usage of digital mapping tools to increase participation in planning processes and political negotiation, both in public and private contexts (Schlossberg & Shuford 2005, Sieber 2006, Rinner et al. 2008). Over the past 20 years, groups of planners, politicians, activists, and citizens have engaged in forms of computer-aided (or mediated) activities revolving around complex spatial problems that involve conflicting views and claims (Kwaku Kyem 2004). A typical PGIS is able to store, visualize, analyze, and annotate spatial objects in a collaborative manner, often with a strong cartographic component. Such systems are designed to enable multiple stakeholders to create and edit data and interact with other participants (Dunn 2007). PGIS application domains include land use zoning (Brown et al. 2018), urban planning (Maquil et al. 2018), indigenous land rights (Brown & Kyttä 2018), assessment of environmental impact (Evans et al. 2004), and marine spatial planning (Mare Nostrum 2016).

While PGIS projects in the 1990s ran on unashamedly hard-to-use desktop GIS manned by experts, the following 15 years witnessed a boom of increasingly cheap and portable devices, coupled with the rise of ubiquitous web maps (Haklay et al. 2008, Smith 2016). Many PGIS project assemble ad-hoc systems using existing Web-mapping platforms,[1] while dedicated platforms include Commonplace.is and SeaSketch.[2] In parallel, the diffusion of smartphones since 2007 has created a novel category of computing platforms, characterized by smaller screens, sensors, touch interfaces, and well-integrated, native apps.[3] These rapid technological changes generally raised the expectations of users that interact with user-friendly, reliable, consistent, responsive, and aesthetically pleasing systems. As a result, the issue of usability is not an afterthought, but a central concern in an increasingly competitive software ecosystem.

Originating in the study of ergonomics and human-computer interaction, the term usability refers to how easy a user interface is to use, with respect to learnability, efficiency, memorability, errors, satisfaction, and other dimensions (Nielsen 1999, 2012*a*). Developers across domains have pledged to adopt user-centered design, emphasizing the needs of the user as a driving factor – or at least paying lip service to this idea. Usability engineering, user experience (UX), and their cognate fields are enjoying considerable popularity, and diverse methods and techniques are blossoming in a growing marketplace (Hassenzahl & Tractinsky 2006, Garrett 2010).

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[1] `http://www.ppgis.net/resources/geoweb-applications` – All URLs were accessed in November 2018 and can be found on the Wayback Machine at `https://archive.org/web`.

[2] `https://www.commonplace.is`, `https://www.seasketch.org`

[3] See for example ESRI's apps at `http://www.esri.com/software/apps`

The context of PGIS has peculiarities that clearly distinguish it from other applications and domains. Unlike large commercial websites, PGIS tend to have a limited number of users, usually on the order of hundreds or thousands at most. The development of PGIS tools tends to be performed by small teams on tight budgets, in the framework of academic, non-profit, or governmental projects. As disadvantaged communities are often the focus of PGIS initiatives, users' digital literacy might vary dramatically. It is also important to note that, in projects using PGIS, social, political, and cultural obstacles can be harder to overcome than tools' usability (Brown et al. 2017). Despite the general interest in usability engineering in GIScience (Slocum et al. 2001, Raubal 2009), our knowledge of usability for PGIS remain fragmented and, because of technical changes, rapidly obsolescent (Haklay 2010).

For this reason, we argue that specific usability guidelines and approaches should be developed for PGIS, coordinating the sparse efforts in the field. Considering the typical technical and institutional context of PGIS projects, we aim at developing a PGIS usability evaluation framework, with a set of clear guidelines, practices, and tools that will help managers and developers. As the first step in this direction, we focus on the issue of the measurement of the perception of overall usability of a PGIS.

Quantifying the subjective perception of usability has long been identified as a key aspect of usability engineering (Brooke 2013). If users find a system not usable, these impressions will impact negatively on the system's adoption, regardless of other, more objectively measurable, aspects. In this context, the System Usability Scale (SUS), designed by a usability engineer in the 1980s, emerged as simple and useful scheme to measure the overall level of usability of a software system (Brooke 1996). Based on ten questions, the SUS captures in a repeatable and consistent way how usable a system is perceived to be, and enables rapid comparisons with previous or competing systems. The questionnaire has stood up to scrutiny of statisticians and usability researchers for 30 years, without revealing fundamental flaws (Sauro 2011).

Considering the limited resources and constraints of PGIS projects, the emphasis should be on inexpensive approaches, providing practical support and guidance to developers, without the need for complex protocols and laboratory experiments. This family of *lean* or *discount* techniques has been promoted by several leading usability researchers, arguing that frequent, informal evaluations are to be preferred to rare, expensive, and formal ones (Nielsen 2009, Krug 2014). Following this lean approach to usability, we tackled the problem of measuring the user perception of usability in PGIS.

Starting from the SUS, we designed a set of questions that capture central aspects of PGIS with simple, unambiguous language. This process resulted in the Participatory GIS Usability Scale (PGUS), a freely-available and general questionnaire that can be deployed by any PGIS practitioner. This questionnaire is available online under a Creative Commons license to be used, updated, refined, and extended by

PGIS practitioners.[4] Indeed, this method is not meant to replace existing usability assessment approaches, but rather to provide a complementary low-cost tool.

The PGUS was developed and evaluated on SeaSketch, a PGIS for marine spatial planning created at the University of California, Santa Barbara.[5] SeaSketch is an entirely web-based platform for collaborative spatial planning and analytics, aimed at facilitating the creation, evaluation, and sharing of spatial sketches, i.e., map-based scenarios that intend to capture and communicate the user's viewpoint on planning problems. The system is currently deployed in several planning projects, and has, relatively to the field of PGIS, a large user base of about 3,200 people. The PGUS was developed iteratively with the collaboration and input of SeaSketch users. A set of 175 responses was obtained from the community, generally positive feedback about the tool's usability, while also identifying several areas of improvement that informed the team's development work.

In the remainder of this paper, we review the state of the art in the usability of PGIS (Section 2). SeaSketch provided a suitable case study (Section 3). Subsequently, we lay the groundwork for a lean usability method for PGIS (Section 4). Section 5 outlines the Participatory GIS Usability Scale (PGUS), while Section 6 describes the results of the PGUS applied to SeaSketch. Finally, we draw conclusions from this experience and we indicate directions for future work (Section 7).

2 Usability, web design, and PGIS

The need for better usability in PGIS has been widely acknowledged (Haklay & Tobón 2003, Aditya 2010, Skarlatidou et al. 2013). The cost of poor usability in PGIS projects is high, as participants can quickly come to believe that the new technology might not support the decision-making process or even hamper it (Haklay 2010). Project funders might regret the investment and reduce future support for similar initiatives. Engineering high usability for a PGIS is therefore of crucial importance to avoid such unfortunate situations.

2.1 Measuring usability

Producing reliable observations on the complex interactions between people and machines presents many challenges. Usability is not directly observable, and is articulated in several interrelated dimensions, such as efficiency (the speed of execution of tasks), effectiveness (the quality of the solutions produced through the system), satisfaction (the emotions experienced when using a system), and learnability (the ease to remember procedures on the system) (Nielsen 1999). The conceptual

[4] `http://github.com/andrea-ballatore/pgis-usability`

[5] `http://www.seasketch.org`

organization of these dimensions and their priority varies across research communities and individual authors. Usability engineers often rely on qualitative methods to identify specific issues, and on quantitative approaches to detect broad trends that would not be observable qualitatively (Nielsen 2004).

As Nielsen (2012*b*) pointed out, some aspects of usability are measurable by considering objective outcomes of user behavior, while others depend on the subjective and affective relationship of the user with the system. For instance, the efficiency of a system in supporting a task can be measured in terms of success rate and elapsed time. By contrast, the measurement of user satisfaction must involve subjective judgments. Unsurprisingly, users tend to be more satisfied with better-performing systems, but the correlation between objective performance and subjective satisfaction is not absolute, requiring distinct measurement strategies (Frøkjær et al. 2000).

The need to study systematically these objective and subjective dimensions prompted the design of several metrics and questionnaires (Hornbæk 2006). Notably, usability experts can make users perform tasks, counting their successes and failures in a binary way, studying their recurring errors, or looking the quality and completeness of their solutions to non-binary problems. Usability metrics can capture the precision of manipulation of interface elements (i.e., the ratio between intentional and unintentional actions on the interface). The learnability of a system can be quantified through measures of recall (the ability of the users to remember how to perform tasks or to recall information seen on the system's interface). Tasks can be designed to measure the user's cognitive load and efforts when communicating system-based procedures to other users.

To measure subjective dimensions of usability, questionnaires are fundamental tools. In particular, the standardization of questionnaires has been identified as an important way to measure success over time and compare systems (Hornbæk 2006). For general usability, several questionnaires have emerged as de facto standards, and have been applied to large numbers of systems and users. Notably, Lewis designed questionnaires for IBM in the 1990s, which have been widely used (Lewis 1995). Brooke's System Usability Scale (SUS) (Brooke 1996, 2013, Sauro 2011) is one of the most successful usability questionnaires, and provided the template for our work that aims at providing a standardized questionnaire for PGIS. The SUS was selected over competing questionnaires because of its simplicity and high statistical reliability.

2.2 Usability and web design

As Norman (2013) claims, many usability principles remain valid over time and in diverse application areas. However, as web browsers become increasingly powerful and influenced by the adoption of smartphones, the web is changing rapidly as an interactive medium. Standards like HTML5, CSS3, and JavaScript frameworks enable the design of full-fledged web-based applications, often with strong geospatial components. Therefore, it is reasonable to assume that PGIS will increasingly be web-based, and these trends should be considered with particular attention to design usable PGIS.

In recent years, web technologies have greatly improved, and great strides in the usability of websites have been made (Nielsen & Budiu 2013). As happened previously with desktop software development, web development increasingly relies on frameworks that support the design of standardized, consistent interfaces. Furthermore, in recent years, large actors in the US have developed their own usability philosophies, such as Apple's iOS Human Interface Guidelines, Google's Material Design, and the US Government's Usability.gov. These guidelines have wide-ranging effects, well beyond the respective corporate platforms and websites.

Seemingly commonsensical principles of web design have been challenged by usability and UX research. The lighthearted website *UX Myths* provides a useful summary of such received ideas that appear to have no empirical basis.[6] For instance, the *three-click rule* states that a user of a website should be able to find any information with no more than three mouse clicks, while this shows no correlation with performance or user satisfaction in real systems. Moreover, trends such as the so-called responsive design suggest to re-think interfaces as fluidly adaptable to any device, ranging from high-resolution large screens to typical smartphones, and even to smart watches (Gardner 2011). Maintaining high usability across radically different devices confronts PGIS developers and designers with new, cross-media challenges.

2.3 Usability of PGIS

PGIS is not a well-defined area, and its boundaries are often difficult to discern. Preferring the term Public and Participatory GIS (PPGIS), geographers and urban planners aim at understanding the interplay of the social, institutional, political, and technological dimensions in PGIS projects (Sieber 2006, Balram & Dragićević 2005, Forrester & Cinderby 2013).

While an account of these debates lies outside of the scope of this article, it is worth noting that PGIS is studied in its social and political effects, questioning whether it actually supports marginalized groups and social and environmental justice in real-world contexts (Brown 2012). Indeed, higher usability cannot overcome deeper constraints and barriers by itself, but non-usable PGIS have a slimmer chance to succeed.

Among the dozens of books published about usability over the past 20 years (e.g. Norman 2013, Krug 2014), only a textbook edited by Haklay (2010) focuses on the specific context of GIS, providing a valuable overview of the field, guidelines and case studies. In parallel, the usability of web maps, central to modern PGIS, has received some attention (Nivala et al. 2008, Roth 2015). Unfortunately, the

[6] `http://uxmyths.com`

highly specific context of PGIS studies and the rapid changes in web and mobile technologies limit the generalizability and currency of these findings.

The rare research in PGIS usability highlights that participants' previous web and GIS experience tends to affect the perceived usability of a system, confirming the challenges of usability design for participants with low levels of digital literacy (Stevens et al. 2014). Occasionally, in highly collaborative contexts, "old" media such as translucent maps appear more usable than "new" mobile interactive maps (Aditya 2010). In tense political contexts, the issue of trust has also received attention (Skarlatidou et al. 2013), and "serious games" have been proposed to add a playful component to PGIS, increasing public engagement (Poplin 2012).

Desktop-based systems such as ArcGIS are influenced by conventions and choices of their native platforms (i.e. Microsoft Windows), and the same principle applies to current GI web and smartphone apps, which are increasingly influenced by Google and Apple guidelines and constraints. Notably, Google Maps has become the de facto standard for reference maps in web applications, determining how hundreds of millions of users experience panning, zooming, and search on digital maps. It is still unclear how PGIS design practices should respond to these developments and, as a result, PGIS developers have to make several technical choices.

Hence, we argue that a new wave of usability research is needed to adapt to these recent changes and provide developers with lean, adaptive techniques to maximize the usability of PGIS, within its usually tight institutional and financial constraints. This article initiates this process by tackling the lack of standardized questionnaires for PGIS usability. The next section outlines SeaSketch, a PGIS that provides the real-world context to develop our usability framework and the PGUS.

3 SeaSketch, a web platform for marine spatial planning

SeaSketch is a web-based software service mapping platform that facilitates the planning of ocean space, and is owned by the McClintock Lab at University of California, Santa Barbara.[7] The SeaSketch platform was conceived as a successor to MarineMap, an application used for the collaborative design of marine protected areas in California (Gleason et al. 2010, Merrifield et al. 2013, Goldberg et al. 2016). The platform aims at supporting science-based, stakeholder-driven marine spatial planning in collaborative planning processes.

Marine spatial planning

Marine spatial planning, also referred to as ocean zoning, has as a main goal the coordination of stakeholders in the regulation of the usage of limited coastal resources, combining often divergent economic, social, and environmental objectives (Ehler &

[7] http://www.seasketch.org

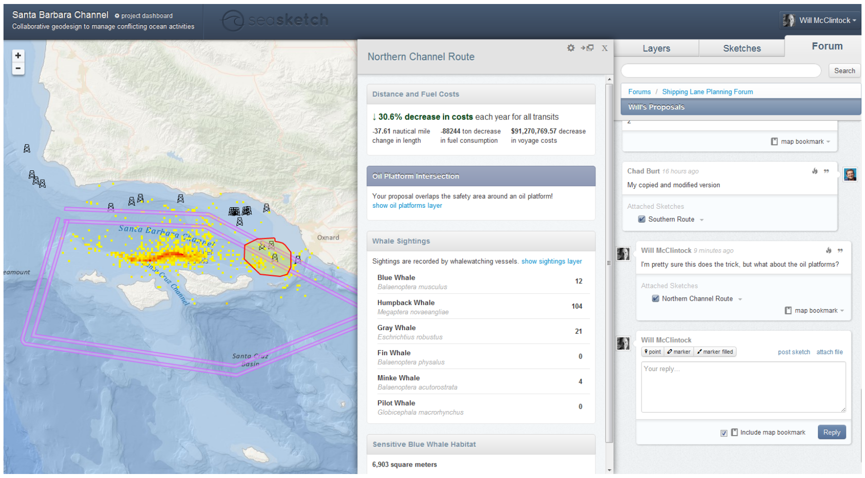

Fig. 1 The SeaSketch interface for collaborative marine spatial planning in the Santa Barbara Channel.

Douvere 2009). For example, marine spatial planning can be used in a coastal region to help fishing companies, local government, and environmentalists generate and analyze different planning options, defining sustainable fishing areas, while protecting endangered species in marine sanctuaries. Marine spatial planning can decrease conflict between stakeholders, improve regulatory efficiency, engage affected communities, and preserve fragile ecosystems, particularly in complex geopolitical contexts (Mare Nostrum 2016). To achieve these ambitious goals, marine spatial planning benefits from transparency and inclusiveness, engaging relevant stakeholders throughout the process.

SeaSketch projects

To date, SeaSketch has been implemented and deployed in over twenty, large-scale planning initiatives including the Blue Halo Initiative in the Caribbean, the Southeast Marine Protection Forum and SeaChange in New Zealand, the Marine Planning Partnership of the North Pacific Coast in British Columbia, the Marine Reserve Zoning process of Galapagos National Park, and the Safe Passages initiative in the Santa Barbara Channel of California.[8] In each case, SeaSketch is used to facilitate face-to-face meetings, in which planners engage stakeholders or members of the general public in the design and evaluation of spatial plans. In most cases, the tool is also used by non-technical stakeholders at home or in community meetings without the assistance of planners.

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[8] For a complete and updated list of projects, see `http://www.seasketch.org/projects`.

The tool

SeaSketch, launched in 2012, was designed for marine spatial planning to collect, evaluate, and analyze data, assessing whether scenarios met planning goals and objectives. The development team has collected feedback from users through the User Voice service,[9] acting upon comments and feature requests, as part of an Agile development process. Figure 1 shows the interface of a SeaSketch-based system tailored to support collaborative marine spatial planning in the Santa Barbara Channel in California.

Users are invited to view relevant data and information, take surveys, and sketch out their plan ideas. These prospective scenarios are automatically evaluated based on science and policy guidelines and may be shared with other users in map-based discussion forums. These iterative design and analysis, often called geodesign (Goodchild 2010), encourage users to collaboratively build scenarios with broad stakeholder support.

In terms of interaction with spatial information, typical operations for planners and stakeholders include answering surveys to contribute to spatial datasets about human activities and resources in and around the ocean, viewing and querying map layers, sketching plans (e.g., marine protected areas, shipping lanes, tourism zones), and sharing and discussing plans in map-based forums. Project administrators, in addition, have control over the map extent, map layers, users and groups with access permissions, discussion forums, surveys, and they can analyze user activity in a project dashboard.

Usability of SeaSketch

While SeaSketch has been overall successful in its many deployments, the user feedback collected through the Agile development suggests that several aspects of its usability might be improved. For example, some users seem to be confused about how to sketch and analyze geometries, despite the contextual help intended to guide them through the process. Furthermore, user forums have seen limited usage and appear underutilized, probably for lack of clear feedback about privacy settings. Before addressing these specific issues, we realized that there was no simple and yet structured way to probe the perceived usability, and SeaSketch and its user base provide the ideal ground to advance the general knowledge about usability for PGIS. Lean usability, we argue in the next section, provides a suitable framework for this goal.

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[9] `http://uservoice.com`

4 A lean usability framework for PGIS

In a fast-changing technical landscape, usability for PGIS needs to be highly adaptive and flexible. In this section, we outline a lean usability framework for PGIS, based on our experience with the SeaSketch platform and user community. By lean usability, we mean usability engineering and evaluation techniques that favor informal, continuous, multi-modal, small-scale, iterative approaches to evaluating PGIS tools. Our lean usability framework has the following objectives:

- Evaluate the overall usability of the system to a given group of users.
- Help developers identify usability issues in current products and gain actionable insights from their users' behavior.
- Tighten the feedback loop between users and developers, tapping multi-modal computer-mediated communication.
- Embed continuous usability evaluation into the platform itself, not only in the form of ad-hoc interventions.
- Support design choices with evidence collected from users in natural settings.

Espousing Nielsen's viewpoint (Nielsen 2004), we argue that typical PGIS projects do not have enough resources to generate reliable findings, such as in A/B studies, where alternative versions of an interface are compared on a randomized sample of users. Lab-based evaluations are complex and expensive, and fail to capture the diverse user bases and natural contexts of application of PGIS. Further principles include that observing what users do reveals more than asking users what they want (Krug 2014), and that implicit feedback analysis offers opportunities too (Ballatore & Bertolotto 2011). Based on the usability testing classification by Rohrer (Rohrer 2008), we propose a combination of the following methods for a typical PGIS.

Heuristic usability evaluations. A usability expert, external to the developers' team, reviews the products informally based on general usability principles such as consistency and standards, error prevention, and recognition rather than recall. Such evaluations can be seen as a premise to the other techniques.

User feedback buttons. Feedback buttons and links are placed in the products to allow users to express opinions, and can be closed- or open-ended. Feedback forms must be contextual, allowing users to comment on specific parts of the interface or tasks, rather than on the product in general. The entire feedback procedure must be extremely fast (usually shorter than 30 seconds), and should encourage informality.

Intercept surveys. Short and contextual web questionnaires can be triggered within the product, asking users focused questions, without making them leave the application. Compared to email surveys, intercept surveys capture feedback from users while they are performing tasks. To limit the impact on user attention, intercept surveys must be triggered rarely and preferably not during sensitive tasks. If triggered at the beginning or end of sessions, such surveys can be used to collect the intentions of users, illuminating their behavior.

Email surveys. Traditional email surveys can be used as a complement to intercept surveys to reach different users, particularly those who use the products infrequently. While the response rate is expected to be lower than for intercept surveys, email surveys can be longer and more detailed. The PGUS was disseminated as an email survey.

Implicit feedback. Modern web analytics packages can provide insights about user behavior, quietly collecting information about users' geographic location and devices, page views, clicks, taps, and even mouse movements. Implicit feedback analysis can reveal recurring usage patterns, providing actionable evidence to developers, for example suggesting the removal of an unused button or a shortcut to reach a frequently used panel. Concerns for user privacy are obviously paramount in PGIS and need to be addressed explicitly with an opt-in model.

To implement our first objective, i.e., the evaluation of the overall usability of the system, we designed a usability scale for PGIS, described in the next section.

5 Design of the Participatory GIS Usability Scale (PGUS)

As a first step towards the development of a usability framework for PGIS, we started by quantifying the perceived usability of a system on a numeric scale. Measuring the overall usability of a system is an obvious starting point to then proceed to other diagnostic techniques, and facilitates direct comparison between similar systems.

System Usability Scale (SUS)

In usability research, the System Usability Scale (SUS), originally conceived in 1986, has established itself as a standard tool for this kind of measurement (Brooke 2013). In SUS, users are asked to score ten items such as "I think that I would like to use this system frequently" and "I found the system unnecessarily complex" on a 5-point Likert scale, ranging from "strongly agree" to "strongly disagree." These scores are then aggregated and converted into a final score from 0 (unusable) to 100 (extremely usable). SUS has been used in research and industry for 30 years, and is considered extremely general and reliable (Bangor et al. 2008, Sauro 2011).

Design process

PGUS was designed in collaboration with members of the SeaSketch user community. The design of SUS involved the evaluation of two systems evaluated by participants, who filled in an initial questionnaire of 50 questions. From these questions, ten were selected based on inter-correlations. In the design process of PGUS, we did not have multiple systems to compare and, for this reason, we adopted a

Table 1 Participatory GIS Usability Scale (PGUS) – v1

(A) *User interface*
1. The terms used in the system are clear.
2. It is easy to move through different parts of the system.
3. The error messages are easy to understand.
4. The delay between operations is acceptable.
5. Returning to the homepage is easy.

(B) *Spatial interface*
1. It is easy to move to a new location on the map.
2. It is easy to zoom in and out on the map.
3. I can create new content easily.
4. I can easily access information about what is displayed in the map.
5. The visual edits on the map take effect immediately.

(C) *Learnability*
1. I am confident using the system.
2. It is easy to remember how to perform tasks.
3. Discovering new features by trial and error is easy.
4. I find the help resources useful.
5. Mistakes can be easily undone.

(D) *Effectiveness*
1. The system gives me the tools to reach my goals.
2. The system is reliable.
3. I can complete tasks that would be impossible without the system.
4. The system increases my participation in the project.
5. I would recommend this system to others.

(E) *Communication*
1. The system helps me communicate my ideas to other participants.
2. I always understand what the system is showing.
3. The maps are easy to understand.
4. I can express my opinion about other participants' ideas.
5. When I have a problem, somebody can help me.

different approach. Starting from an initial set of 40 questions, we ask a sample of 16 users to provide feedback on the questionnaire overall, and specifically on each question. The user sample was designed to include expert administrators, intermediate users, and novices. Questions flagged as unclear, ambiguous or irrelevant were either rephrased, edited, or removed. After two iterations, the questionnaire was streamlined to 25 questions, marked as clear from all sample users. To maximize the response rate of the PGUS, we kept the maximum time of completion at about 5 minutes, deemed acceptable by the sample users (see Section 6).

Questions

The resulting questionnaire contains 25 questions, formulated in simple English, explicitly avoiding GIS jargon (see Table 1). It is worth noting that, although the SUS questions include positive and negative phrasing, we only included positive questions. Not mixing positive and negative phrasing reduces the possibility of misinterpretation and user error (Brooke 2013), making the score calculation simpler. However, it is important to note that this approach might reduce the participant's attention devoted to each question.

The questions aim at capturing aspects that are common across PGIS in different domains. The questions are grouped in five themes, which represent complementary dimensions of the usability of a PGIS. These themes include (i) *user interface* (the visible part of the system), (ii) *spatial interface* (the interaction with spatial data), (iii) *learnability* (how easy it is to learn how to use the system), (iv) *effectiveness* (how the system supports the user goals), and (v) *communication* (how the system supports communication with other users and stakeholders). The names of the themes should not be displayed to the respondents taking the questionnaire, and are only for internal use. To reduce ordering bias, we recommend randomizing the order of the questions.

Scoring

Following SUS, the answer to a question is expressed on 5-point Likert scale, with each point corresponding to a score between 0 and 4: "Strongly disagree" (0), "Disagree" (1), "Neither agree nor disagree" (2), "Agree" (3), and "Strongly agree" (4). The final PGUS score, in analogy with SUS, is calculated by summing all the ratings, and ranges between 0 (unusable) and 100 (extremely usable). By keeping the scoring as simple as possible, PGUS avoids one of the common criticisms to SUS, reducing the possibility of error. The practitioner should bear in mind that the score does not represent a percentage of usability, and score comparisons across systems should be done by treating the data as ranked.

Resources and license

The current version (v1) of the questionnaire can be found in machine-readable formats on GitHub,[10] and can be applied to any PGIS. To ensure maximum reusability in research and industry alike, PGUS is released as Open Data under a Creative Commons Attribution Share-Alike 4.0 (CC-BY-SA-4.0).

[10] `http://github.com/andrea-ballatore/pgis-usability`

6 A case study on SeaSketch

Table 2 The user questionnaire that was designed to collect information about the demography and familiarity with SeaSketch of participants. Note that this is not part of PGUS.

	Welcome to the SeaSketch User Survey! We are the SeaSketch team, and we are collecting feedback to improve SeaSketch. This survey is strictly anonymous, and it will take less than 5 minutes to complete it. Please note that this survey only applies if you used SeaSketch. If you have any questions about this survey, please contact us at <email>.
Q1	What is your age? *<17 or younger; 18-20; 21-29; 30-39; 40-49; 50-59; 60 or older>*
Q2	Are you male or female? *<Male; Female>*
Q3	What is the highest level of education you have completed? *< Did not attend school, ..., Completed graduate school>*
Q4	How would you rate your web experience prior to working with SeaSketch? *<Beginner; Intermediate; Expert>*
Q5	How long have you used SeaSketch for? *<1-10 hours; 11-20 hours; 21 or more hours>*
Q6	How would you rate your knowledge of SeaSketch? *<Beginner; Intermediate; Expert>*
Q7	Have you ever contributed to other public participatory projects? *<Yes; No>*
Q8	What problems do you encounter using SeaSketch? *<Open answer>*
Q9	What existing features of SeaSketch need improving? *<Open answer>*
Q10	What new features would you like SeaSketch to offer? *<Open answer>*

The PGUS was implemented and disseminated to the SeaSketch user base, in order to probe the usability of the platform along multiple dimensions. For the purpose of this study, the PGUS was complemented by demographic and project-specific questions, aimed at understanding the composition of the SeaSketch user base and their self-assessed level of expertise. For the sake of completeness, we include these additional ten questions in Table 2, which might be used as a template in other PGIS projects.

The survey was disseminated by email to the SeaSketch user community through the SurveyMonkey web platform.[11] The invitation was delivered to a set of 3,274 user emails, including inactive and occasional users. These calls obtained 288 anonymous responses, followed by a tail of 23 late responses, for a total of 311 responses. Out of all responses, 59% were complete, while the other respondents did not complete the questionnaire. The total number of complete responses is therefore 181, corresponding to 6% of the whole user base.

[11] The survey was disseminated on October 19, 2015, with a reminder on October 26.

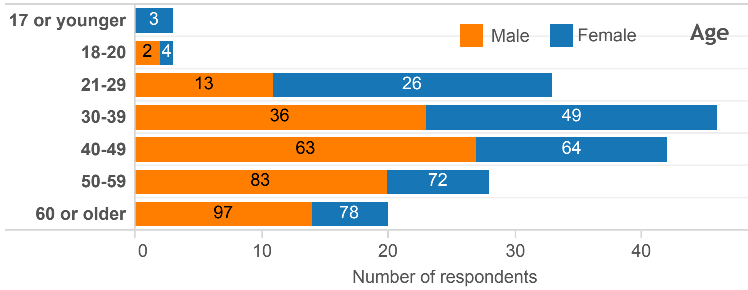

Fig. 2 Age of the respondents, including number of males and females (N=175).

Completion time

The PGUS is designed to maximize user participation and completion time is therefore an important dimension to observe. In the set of complete responses, we calculated the minutes elapsed between the beginning and the end of the user sessions. This resulted in 181 completion times, with the following distribution: minimum (0.8 minutes), 1st quartile (2.8 minutes), median (4.2 minutes), 3rd quartile (7.4 minutes), and maximum (2,611 minutes). Note that these times include the ten questions about the user, which are not part of the PGUS.

Hence, based on the median of 4.2 minutes, we can confirm that the completion time for PGUS is well below 5 minutes. In this distribution, the tail of low completion times is of particular interest to detect invalid responses. Considering the length and complexity of the questionnaire, we estimated that responses that took less than 90 seconds were generated without comprehending its content. Six responses were therefore discarded, leaving 175 valid responses in the dataset.

Demographics

Out of 175 respondents, 97 males (55%) and 78 females (45%). The age of respondents is illustrated in Figure 2, showing that 26% are in the 30-39 group, followed by 24% in 40-49 group. Another demographic dimension is the level of education, showed in Figure 3. Surprisingly, 60% of respondents completed graduate school, and 22% graduated from college, indicating a very high level of education of SeaSketch users, considerably higher than other PGIS projects.

Two dimensions aim at capturing the level of experience of users with the tool, and the total number of hours of prior usage. As shown in Figure 4, 25% of respondents considered themselves as beginners, followed by a 40% of intermediate, and a 35% of experts. This self-assessment is consistent with the number of estimated hours of exposure to the tool. Apart from the level of education, heavily skewed towards the highest part of the range, the sample of 175 appears to cover in a bal-

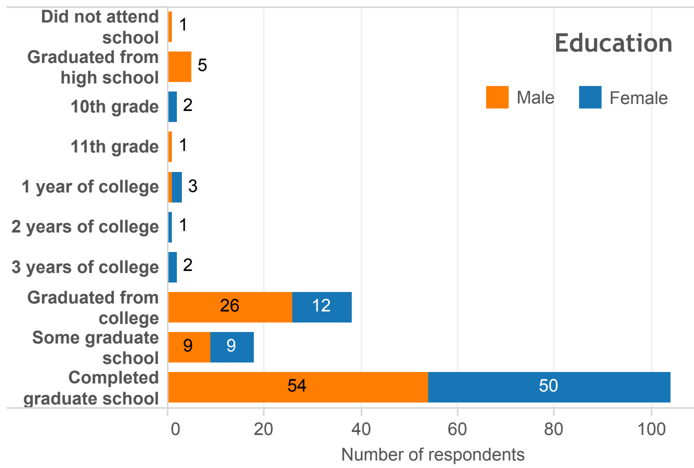

Fig. 3 Level of education of the respondents, including number of males and females (N=175).

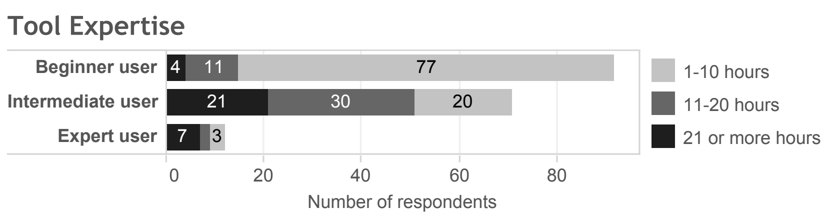

Fig. 4 Self-assessed expertise of the respondents (N=175).

anced way males and females, as well as a broad range of age groups and levels of expertise.

PGUS scores

The ratings in the Likert scales were used to calculate 175 usability scores, one for each respondent. The distribution of these scores goes from a minimum of 28 to a maximum of 100, with the first quartile being 59, and the third quartile being 74. More importantly, the median PGUS score is 67. Figure 5 shows the density of the scores, highlighting the median. Subsequently, we analyzed scores to find correlations with the demographic characteristics of respondents. Using the non-parametric Kruskal-Wallis rank sum test (Sprent & Smeeton 2007), no significant difference was detected between scores by males and females.

The age of respondents has a small effect on the variance of the PGUS scores. The Kruskal-Wallis test detects significant differences among the age groups (chi-squared 17.8 on 6 degrees of freedom, with $p < 0.01$). Treating age groups and

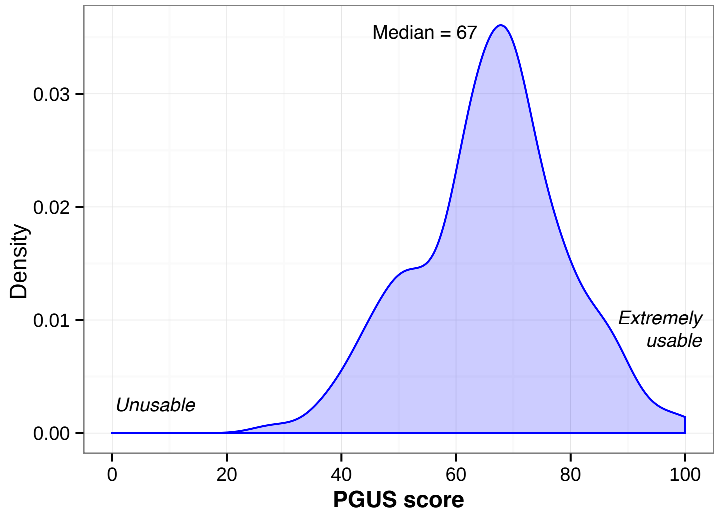

Fig. 5 Density of PGUS scores (N=175).

PGUS scores as ordinal variables, a weak inverse correlation can be observed, indicating that young users tend to find the system more usable than older users (Spearman's $\rho = -0.25$, with $p < 0.01$). No other significant correlations were identified between PGUS scores and the self-assessed level of expertise and hours of exposure to the tool.

PGUS Likert ratings

After discussing the PGUS scores, which captures the overall perception of usability, it is useful to consider the detailed Likert ratings to the 25 questions that are used in the score calculation. Overall, the 175 respondents expressed 4,375 ratings on the Likert scale. The counts of ratings for each question of the PGUS are displayed in Figure 6. The figure shows the sum of the PGUS scores only for each specific question, with a distance from the mean expressed as a percentage. For example, question D4 ("The system increases my participation in the project") obtains score 462, slightly below average (-0.1%), while E3 ("The maps are easy to understand") received a total score of 523, (13.1% higher than average).

The most positive answers were obtained by questions B2 and D5 ("It is easy to zoom in and out on the map" and "I would recommend this system to others."). By contrast, respondents rated questions D3 and E5 ("I can complete tasks that would be impossible without the system." and "When I have a problem, somebody can help me.") as the most negative. As is possible to see in Figure 6, the respondents expressed predominantly positive ratings (agree or strongly agree) on 19 out

	Question	Sum of PGUS scores	Mean PGUS score	Distance from mean (%)	Strongly disagree	Disagree	Neither	Agree	Strongly agree
A1	The terms used in the system are clear.	466	67	0.8	0	14	48	96	17
A2	It is easy to move through different parts of the system.	471	67	1.9	0	18	40	95	22
A3	The error messages are easy to understand.	424	61	-8.3	1	11	85	69	9
A4	The delay between operations is acceptable.	451	64	-2.4	3	18	47	89	18
A5	Returning to the homepage is easy.	495	71	7.1	0	7	41	102	25
B1	It is easy to move to a new location on the map.	518	74	12.1	1	8	29	96	41
B2	It is easy to zoom in and out on the map.	532	76	15.1	1	8	18	104	44
B3	I can create new content easily.	429	61	-7.2	3	17	70	68	17
B4	I can easily access information about what is displayed in the map.	473	68	2.3	2	20	29	101	23
B5	The visual edits on the map take effect immediately.	450	64	-2.6	1	17	59	77	21
C1	I am confident using the system.	428	61	-7.4	5	20	58	76	16
C2	It is easy to remember how to perform tasks.	456	65	-1.3	0	16	52	92	15
C3	Discovering new features by trial and error is easy.	443	63	-4.2	0	20	59	79	17
C4	I find the help resources useful.	452	65	-2.2	0	9	74	73	19
C5	Mistakes can be easily undone.	436	62	-5.7	0	12	78	72	13
D1	The system gives me the tools to reach my goals.	460	66	-0.5	6	7	53	89	20
D2	The system is reliable.	476	68	3	2	8	53	86	26
D3	I can complete tasks that would be impossible without the system.	406	58	-12.2	8	32	58	50	27
D4	The system increases my participation in the project.	462	66	-0.1	3	16	51	76	29
D5	I would recommend this system to others.	529	76	14.4	3	8	22	91	51
E1	The system helps me communicate my ideas to other participants.	480	69	3.8	3	5	55	83	29
E2	I always understand what the system is showing.	425	61	-8.1	2	30	52	73	18
E3	The maps are easy to understand.	523	75	13.1	0	8	24	105	38
E4	I can express my opinion about other participants' ideas.	450	64	-2.6	0	7	85	59	24
E5	When I have a problem, somebody can help me.	421	60	-8.9	2	15	86	54	18

Fig. 6 PGUS scores grouped by questions (N=175). The colors highlight the mean score for each question (white-green scale), the distance of each question from the mean (red-green scale), and the number of ratings (white-blue scale). The mean of the scores is 462.2.

	Theme	Sum of PGUS scores	Mean PGUS score	Distance from mean (%)	Strongly disagree	Disagree	Neither	Agree	Strongly agree	Negative opinion (%)	Neutral opinion (%)	Positive opinion (%)
A	User interface	2307	**65.9**	-0.2	4	68	261	451	91	8.2	29.8	61.9
B	Spatial interface	2402	**68.6**	3.9	8	70	205	446	146	8.9	23.4	67.7
C	Learnability	2215	**63.3**	-4.2	5	77	321	392	80	9.4	36.7	53.9
D	Effectiveness	2333	**66.7**	0.9	22	71	237	392	153	10.6	27.1	62.3
E	Communication	2299	**65.7**	-0.5	7	65	302	374	127	8.2	34.5	57.3

Fig. 7 PGUS scores grouped by themes (N=175). Mean group score: 2311.2.

of 25 questions (76%), indicating a generally positive perception of the usability of SeaSketch.

The questions are grouped in five themes. Figure 7 illustrates the same scores of Figure 6, but grouped by themes. In addition, the figure aggregates the ratings into three groups (negative, neutral, and positive), showing percentages of the respondents. For example, 62.3% of respondents gave a positive opinion about questions in the theme *effectiveness*. By analysing the distance from the mean, expressed as a percentage, we note that *spatial interface* is above average (3.9%), while the theme *learnability* is below average (-4.2%). Based on these considerations, it is possible to state that the variation across questions and groups is contained between -12.2% and 15.1%, without showing any extreme variation. The variation is even lower when observing the five themes, ranging from -4.2% to 3.9%. As suggested by Brooke (2013), uniformity of ratings is a further indicator of the soundness of the questionnaire.

Limitations

This exploration of SeaSketch with PGUS was useful to the development team, revealing different facets of the usability of the tool. However, this initial version of the questionnaire has important limitations that should be borne in mind. This questionnaire should be analyzed in terms of validity (the measurement is accurate) and reliability (the measurement is consistent). Usability judgments are subjective by definition, as opposed to performance metrics that can be assessed more objective (e.g., execution time of a task). As a result, the validity of PGUS is a complex issue, and we assessed it with a qualitative *content validity* assessment, based on discussions with a sample of participants from the SeaSketch community to ensure the relevance and the clarity of questions. As we did not have access to a PGIS that is well-known for poor usability, we could not assess validity with comparative methods. To assess PGUS reliability, we have observed good internal consistency. Repeating the assessment over time on different platforms is the ideal way further ensuring reliability. For both validity and reliability, we hope that the research community will use PGUS in diverse contexts and share the results, generating insights and possible improvements that are hard to identify within a single PGIS project.

The meaning of the PGUS score is at the moment only interpretable in relative terms, for example stating how the judgment of two users differ and whether a facet is perceived as more or less usable than another one. Even in well-established surveys like SUS, it is not trivial to translate the 0-100 scores into meaningful adjectives, such as "poor" and "excellent," establishing general guidelines, e.g., scores lower than 50 indicate unacceptable usability (Bangor et al. 2008). Applying PGUS to other systems appears necessary to gather more knowledge and ascertain typical scores for practitioners.

While PGUS aims at being broadly applicable to any PGUS, some questions are likely to be more relevant than others to specific problems. For example, "I can create new content easily" might not apply to visualization-only tools. In this sense, there is a tension between the advantages of a standardized questionnaire and ad-hoc solutions that will better fit the specificities of a project. Other limitations concern the thematic and semantic scope of PGUS. Some questions are about the content of the platform, rather than just about the user interface ("the maps are easy to understand"). For example, users might create poor quality spatial content on a very usable platform, and vice-versa. More conceptual separation between these aspects would be beneficial. Similarly, the questionnaire includes aspects of usability (e.g., B3) and user experience (e.g., E5). In future versions, it might be beneficial to group those aspects more clearly.

7 Conclusion

PGIS is an important application area for GIS and spatial technologies, with specific challenges and user needs. Despite the remarkable advances in usability in general, it can be argued that PGIS usability research has provided limited insights to developers. In this paper, we have argued that the lean approach to usability is particularly suitable for PGIS, and we have started to outline a set of techniques to embed it into an existing platform. As a case study, we focused on SeaSketch, a web platform for participatory marine spatial planning, currently adopted in numerous projects around the world.

To support usability in PGIS, we proposed to combine heuristic usability evaluations, user feedback buttons, intercept surveys, email surveys, and implicit feedback. These techniques provide multi-modal, flexible probes to collect opinions, with the purpose of identifying usability issues. We expect the deployment of this ensemble of lean techniques in SeaSketch to rapidly uncover usability issues, leading towards the development of comprehensive PGIS usability guidelines, updated to the current technological landscape.

As a first step towards this framework, we designed the Participatory GIS Usability Scale (PGUS), providing a simple and inexpensive mechanism to measure the perceived usability of a PGIS. The PGUS was designed in collaboration with the SeaSketch community, starting from Brooke's SUS, a widely used usability questionnaire (Brooke 2013). This questionnaire contains 25 questions, and quantifies the perceived usability of a system on a scale between 0 and 100. The PGUS was disseminated to the SeaSketch user base, obtaining 175 complete responses. The analysis of the results highlights the perceived strengths and weaknesses of the tool, providing useful indications to the developers.

This article covers the first version of the PGUS, which provides a useful starting point for PGIS practitioners. However, more research and evaluations are needed to further refine the questionnaire, assessing its validity and reliability across different PGIS communities. For example, formal validations of the PGUS can be obtained by measuring correlations with more established questionnaires (Hornbæk 2006), as well as comparing the scores of systems that have known excellent and poor usability.

Of the many challenges in PGIS usability, better information sharing mechanisms and the personalization of the interface for users from different backgrounds are of particular interest (Ballatore & Bertolotto 2015). Moreover, PGIS usability cannot ignore recent trends in web design, such as responsive design and the mobile-first strategy, as they are likely to have a broad impact in the near future of PGIS. Understanding what works and what does not on tablets and smartphones is paramount in the current technical landscape (Nielsen & Budiu 2013). Notably, touch interfaces constitute growing and under-explored media to lower the barriers to participatory spatial systems (Haklay 2010).

Because of its civil and political importance, the future PGIS deserves not only usability evaluation for the sake of efficiency and effectiveness, but better user experience from social and affective viewpoints, reducing the need for skilled facilitators (the "GIS chauffeurs") that are still playing a major role in many projects. The limited empirical evidence and insights that we possess invites further research for GIScientists, software developers, social scientists, and planners to study usability in PGIS. Although usability itself cannot overcome deep social and institutional barriers to participation, more usable tools are essential to maximize the inclusiveness, accessibility, and ultimately the likelihood of success of participatory projects.

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