A Framework to Evaluate User Empowerment in Decision-Making Experiences with Participatory GIS

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Abstract. This paper describes a framework to guide designers on how to investigate UX empowerment by using PGIS to support the decision making process. Investigative questions are proposed and aligned with UX elements in order to facilitate the access to information and its discussion within a community, as well as empower users (decision makers) to act not just as consumers of information and systems, but also as creators of new knowledge. The goal was to guarantee an appropriate gathering and observation of the questions in order to evaluate how particular users tasks can be accomplished in a PGIS while complying with requisites that promote empowerment.

Keywords: User experience · UX · Interdisciplinary · Empowering · PGIS

1 Introduction

When developing a software, it may be competitively advantageous to attract early-adopters [1] and maintain them as returning users by providing a pleasant user experience with the software. A common practice among developers is primarily to share the basic features and tools of a software and provide additional more advanced resources as the user interacts with it. This method is justified by user's behavior studies, which reveal that the user's empowerment capacity increases as he acquires technological skills and does not depend on him being an expert.

In this paper, we examine users' empowerment based on the User eXperiences (UX) while making use of a Participatory Geographic Information System (PGIS). GIS provides vast commands, which allow the user to manipulate large volumes of information through "systems for positioning, data acquisition, data dissemination, and analysis" [2]. It also enables graphical display of complex spatial information, deemed beneficial in decision-making processes [3]. Scenarios of local decision-making can be the following: land use/resource development negotiations, choices of feasible alternatives for environmental management, changes in traffic regulations etc. The increasing demand for the involvement of stakeholders that represent diverse areas of competence in order to reach more comprehensive decisions has been supported by PGIS [4]. This demand extends the use of the tool to non-experts from the initial stages

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of group decision-making in order to empower users by incorporating local-level processes and knowledge [5–7].

Advanced interactive solutions are increasingly identified in GIS (Multimodality [8, 9] and Multiple viewing screens [10]) to provide resources (e.g. pre-determined database of elements, filters) that improve the usability and utility of GIS. Such tools are valuable since GIS is often reported as difficult to maneuver and as an exclusionary technology. The evaluation of users' empowerment levels should not be limited to usability requisites, but also regarding the user's perception of individual empowerment[1] in his UX [11].

Some works explore the users' empowerment in their experiences with GIS for group decision-making. In [4], the feature that is related to user empowerment refers to the laws and regulations that interest the participating groups. Corbett and Keller [5] combine four catalysts of empowerment (information, process, skills, and tools) with two social scales (individuals and community). This combination allows to identify which aspects of change in the condition of an individual or community have an influence on their empowerment. In this paper, the empowerment notion is referred to as the "empowerment capacity" of users, which originates from their interactions, whether they be with the PGIS and/or socially with the community from the study area. This capacity is evaluated based on some UX elements (e.g. the user's role, his acquired technological skill, his successful actions, his shared opinions, and so on), which are collected throughout a group decision-making process.

This paper aims at investigating the existing PGIS solutions that address the following question: Is the geographic information technology ready to empower people without overwhelming/excluding a non-expert user during such process? To answer this question, we analyzed some works that present GIS interaction aspects, collected social and design recommendations from other related disciplines and grouped them to a new framework with UX elements. Subsequently, we elaborated some investigative questions to guide designers when elaborating these types of systems.

The results of those studies reveal that the purpose of promoting a non-expert user's empowerment in the decision-making process before, during and after their UX with GIS is a subject not yet sufficiently explored. We expect this framework to be useful for designers, as it presents requisites for a process that empowers the UX, and indicators that evaluate the non-users ability to manipulate and generate information in GIS.

This article initiates with a short review of the literature on GIS and its fundamental aspects. Then, it presents a survey of the participatory making decision theory in order to identify the key elements needed to elaborate our proposal. Finally, it provides an approach to illustrate the application of such elements.

2 Background in GIS and Problematic in UX with GIS

The main goal of this paper was to investigate how the interaction design of a GIS favors the user's perception of their level of empowerment. Specifically, we have sought to evaluate which items impact the UX of the system analyzed. Some comments regarding those items are reported as we present the works studied.

[1] Individual empowerment is a perceived feeling of greater competence or power [12].

It is worth noting that UX and Usability are not the same concept, even though the former encompasses the latter. The Usability Framework focuses on the interaction factors, and is still clearly task-oriented, which turns out to be a restriction in terms of human factors. The UX is defined by the ISO standard 9241:210 [13] as a “person’s perceptions and responses resulting from the use and/or anticipated use of a product, system or service.” It includes all the users’ emotions, preferences, motivations, and accomplishments that occur before, during and after usage [11]. Of the items investigated in this research, the initial four are closely related to GIS usability while the last focuses on emotional aspects related to the UX. They consist of: (i) Graphic resources to explore information (such as Filters, Dashboards); (ii) The method by which the resources are visually available (e.g. Multiple viewing screens, Multimodality); (iii) Tools that enable the generation of new data and/or information (e.g. templates, Knowledge Discovery tools); (iv) Tools that support decision making (e.g. Integration with Collaborative Social Systems (SS) and Decision Support Systems (DSS)) and; (v) Support for users with different skill and technical levels to engage with UX (e.g. practical examples, perceptions, explanations).

Several PGIS requisites for HCI are reported in a multidisciplinary literature as being useful to support user empowerment. [14] Provides a practical example of how a DSS was used to help stakeholders make better informed decisions regarding housing funding policies, and adjusting housing to a consumer profile by incorporating GIS to facilitate dialogue and produce information. Other sources report on requisites that aid the user in various GIS tasks. In the fields of Artificial Intelligence and Cognitive Science, GIS tools are knowledge based due to their capacity to capture decision-makers’ knowledge and perform automated predictive processes (i.e. Cellular Automata [15]; Fuzzy Concepts [16]; Expert and Knowledge Based Systems [17, 18]). In the fields of HCI and GIS, the requisites evolve around the tool’s capacity to sort through non-deterministic criteria and its usability (i.e. providing user-friendly resources such as Virtual Reality [19] and Multimodality [8, 9]). In HCI and Digital Graphics, tools also seek to facilitate the display of information (i.e. Multiple viewing screens [10] and Mobile 3D architecture [20]).

Even though such examples illustrate the potential of GIS interface to support a variety of disciplines, [4] point out that its effective use still requires a considerable knowledge and is compromised by the “multiple realities” that the technology tries to depict. The poorly integrated and exhaustive amount of operations available makes GIS a complex interface and difficult for non-specialists to navigate outside of a technical setting [21]. Therefore, design recommendations related to the investigated items may assist users to filter the vast expanse of information and maximize the chances that any information they come across is valuable [4].

The simple combination of interdisciplinary requisites and recommendations in one tool is not sufficient to guarantee users empowerment from their experiences with GIS. In order to do so, HCI designers must first understand which elements can enhance the UX, in order to define requisites that allow the stakeholders to effectively manipulate information (interacting with community through GIS, SS, directly face-to-face) and achieve status equal to experts’. In [22], the authors define empowerment as providing users with tools to use and transform information according to their needs. One example of such tool is Approach End-User Programming, which allows users to build new functions in a system from existing resources to CATER to new demands [23]. In Co-design approach, empowerment is reported as when the user becomes the co-author of a system interaction [24].

None of the studies examined have presented a framework for HCI designers to reflect on the necessary resources (personal, informational, technical) to empower users in their UX while using GIS. This shift in power dynamic is enabled by the knowledge obtained from the user interaction with the system, from her/his relations with the context in study to obtain and generate information and her/his participation in collaborative decision processes.

3 Participatory Decision Making with GIS

According to [4], Participatory GIS have all of the capabilities of GIS, with additional features that support group decisions. This section describes three elements that were considered for the proposed framework as they impact the users' empowerment from UX with PGIS: People, Information and Decision-making Process.

3.1 The Profile of the User

When individuals need to make decisions influenced by geography, they take into account the realities of a specific geography. Decisions can be made ad hoc, based on a formal analysis, and/or with the collaboration of others who live in and/or know of the local reality. Independent of how a problem is solved, technology may increase the Decision Makers' (DM) abilities to formulate, frame or assess decision situations. Spatial decision making problems commonly involve three categories of DM stakeholders [4]: a specialist in the subject domain, who usually does not use GIS (known as DM), a technical specialist, who has experience in interaction with GIS (e.g. he is able to elaborate complex queries, to use commands) and a non-specialist user, who uses just macros elaborated by a technical user, for instance. In this text, we will call any of them as user.

3.2 Accessing and Sharing of Information - A Perspective of User Empowerment from HCI

During GIS usage, different scenarios of access to information and communication take place via interfaces, which are investigated in the field of HCI. Information refers to the object that is discussed such as features of the environment, communities' and individuals' needs, objectives by which to measure the successful resolution of an issue, impacts of alternatives and the selection of a preferred alternative option, etc. In such systems, the sharing of relevant information is important to consolidate a community. As the user notices his increased knowledge of certain object, it consequently influences his personal perception of empowerment.

To make better-informed decisions and reduce the complexity of the problem, users must take some actions *before* starting these scenarios. Some actions may include the following: to treat the information to be discussed from the understanding of initial assumptions; to motivate specialists in the subject domain in order to also engage in experiences with GIS; to provide individuals or communities that need to understand geographic information with technological means to access resources (such as internet, open source software, databases); and to promote the accessibility and digital inclusion for individual who is not capable of reading, interpreting data, understanding a map, etc.

Users' actions must also take place *after* use scenarios, in order to evaluate the accuracy of a decision achieved according to users' preferences, regarding how effective and equitable it is. Some actions may include the following: at the end of a session of GIS use, but constantly during a decision process, users must apply strategies in order to raise individual participatory behavior; to measure the perception of personal knowledge building; to communicate widely in the community the results of final decision (as of a voting process); etc.

The HCI researcher can become more sensitive to different issues and solutions by understanding how the user accesses information, makes decisions, communicates, and establishes priorities. The view advocated in this article requires solutions that go beyond the choice of graphics, sounds, gestures, etc. as it considers new factors to measure an increase in user empowerment such as [22]:

- Their role in their community, which becomes more prominent as they transmit knowledge to others;
- Their UX with the technology; which can be measured according to their individual perception of knowledge as they use basic and advanced GIS resources and generate new information, (such as if it is "desirable", "useful", "attractive design" and "valuable") [11];
- Their ability to communicate; which increases as they use new solutions (devices, artifacts, modalities) to express their opinions and feelings in order to achieve a decision. Users' participation usually leads them to engage more in UX.

3.3 Process of Spatial Decision Situations

In Spatial Decision Situations (SDS), one user or a group of users composed of various stakeholders should communicate, identify, explore and solve problems through human–computer dialogue [25]. We define SDS as problems related to the knowledge available, which is usually collected from databases (using data mining algorithms, for instance), but also directly from people (through personal posts, answers to questionnaires, etc.).

This paper presents three stages of the decision-making process, defined by [26], to illustrate the relation of DSS and PGIS. Regarding PGIS, they consist of:

- An Intelligence stage, in which users establish the technologic-socio-economic values, objectives and decision criteria for a determined geography;
- A Design stage, in which users generate a set of feasible solutions about the subject domain; and
- A Choice stage, in which users research and evaluate the option set(s) then select and communicate the final solution.

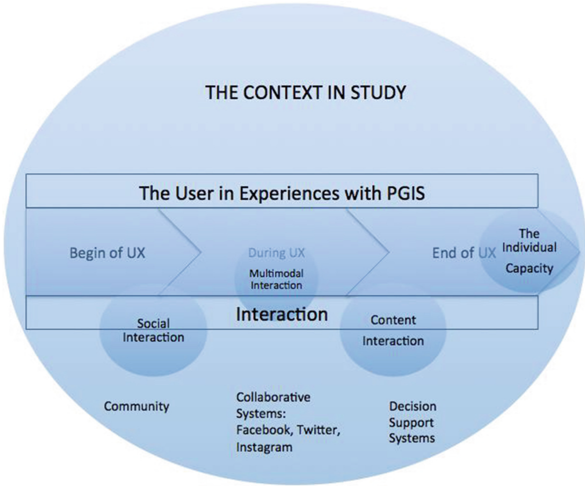

Fig. 1. UXP Framework

4 Proposed Framework

4.1 Characteristics for Empowerment of a UX Through GIS

The framework proposed in this paper is called UXP, which is focused on the design of UX with PGIS to attain individual empowerment. The UXP is formed by characteristics to evaluate user empowerment before, during and after a UX with PGIS (Fig. 1). The initial characteristics (user capacity building and interaction, including social interaction), have an impact on UX hedonic aspects which are related to social-emotional behavior [27] and the latter characteristics (Multimodal, Social Interaction and Content Interaction) are related to the system's pragmatic aspects.

In further detail, the characteristics consist of:

- **Building user capacity;** they refer to the measure (quantitative) or specification (qualitative) of individual knowledge and of the user's perception of individual empowerment resulting from UX. The individual knowledge variable can be measured considering the following variables: the user's perception of his knowledge increasing and his technological skill [11]. The user's perception of individual empowerment variable can be measured considering his role in the community, among other variables;
- **Interaction:** refers to the importance of design to generate, decide and communicate options to achieve collaborative decisions. The occurrence of the interaction is defined by the presence and attributes of the GIS itself (its usability, aesthetics, interoperability with other systems, etc.):
  - **Content Interaction:** refers to the value of GIS information, which may originate from several sources. In interacting with GIS, users absorb, create and modify content (which is when they take ownership of information and engage in experiences). When such interaction takes place without GIS, the information

may originate from the community, and depends on the users role within a context to access it (such as relevance and prestige).
  - **Multimodal Interaction:** this kind of interaction is related to the physical interaction between the user and the device. Examples consist of touching interface patterns, gestures, etc. It also refers to the system capacity necessary for the user to understand the geographic information available and explore it accordingly;
  - **Social Interaction:** refers to support to participation, therefore, user's motivation should be a matter of concern. Designers should define social and content interactions based on the knowledge of what motivates people towards community engagement, and consequently their interactions within such community [11]. This stage is also related to the interoperability of GIS and SS;
- **Context of Interaction:** refers to socio-cultural aspects of the community as well as its information and usage of other social networks and DSS. In HCI studies [13], this variable refers to the characteristics of the environment (Office, Home, Out-of-doors, etc.) and/or ongoing situation (the experience occurring in quiet place, or in a stressful, etc.).

4.2 Investigative Questions of Empowerment

This paper presents a non-preemptive list of questions, which are associated to each framework characteristic. This list originated from our research investigations involving UX in decision-making supported by PGIS, GIS interactive aspects, uses behavior, and users' empowerment capacity [22].

User Capacity Building

- Who is this individual?
- Does the user consider that an increase in knowledge when using the system results in his personal empowerment perception?
- Which factors affect the user's perception of personal empowerment?
- Does users' face-to-face interaction with the community affects such perception of personal empowerment?
- Does the generation of new information, which is based on queries set by the user, consist of an index of increasing personal knowledge and/or empowerment?
- Does the user think that a decision-maker can be independent from an expert?

Content Interaction

- How is information important for the individual? And for the community?
- Who/what is the holder of the information valuable for the community?
- Who/what is the holder of the information about the community?
- Which information and information technology does/don't the community have access?
- How is information assimilated, transmitted and stored in the community?

- How could new technology information be adapted, transformed and used to empower the group?
- How do users appropriate of information?
- How does a subject exchange information with his group and others and what is his role in the process?
- How difficult is it to generate content with GIS information?

Context and Social Interaction

- Who holds the power within a community?
- How does this individual exchange information with her/his group? With other groups?
- How does society interact with this group?
- How organized is the social structure of the community?
- Does access to information poses a threat to one's power?
- Has the group established any rapport or connection with other groups (teachers, researchers, technicians, etc.)?
- Does the group have any rejection or fear of other groups (politics, bureaucrats, etc.)?
- Does any group (terrorists, drug dealers, public authorities, rival tribes, etc.) exert any kind of violence or oppressive power over the community?
- How does the user collect and organize information in partnership with the community to establish queries and take actions in GIS?
- Is the information broadly shared and communicated?
- How does a non-expert user feel while taking part in a group decision-making process?
- When is it possible to state that a decision has been achieved through community consensus?

Multimodal Interaction

- Is this individual full with her/his basic needs?
- How oppressive is the technology for the group?
- How accessible, usable and valuable is the technology for the users?
- How difficult is it for users to understand maps, context, direction and reference points?
- How difficult is it to make use of basic and/or advanced resources in different scenarios while using GIS?

5 Application of the Framework

This paper described an empirical approach to illustrate how designers can apply the questions proposed in the design process of a PGIS. We considered the stages presented in Sect. 3.3 as a part of the integration between the DSS and the GIS being designed, and the social interactions that take place within the system.

Initially, the designer must identify the users' tasks in order to solve group problems accordingly. For instance, on a certain scenario, the user can specify objectives and decision criteria for a determined geography during the intelligence phase; select which of those are feasible during the decision phase; and communicate the final decision in the choice phase [26]. Subsequently, the designer must define UX requirements and information necessary before, during and after the experience with PGIS. Examples of UX requirements consist of: i) a DM stakeholder must be capable of using PGIS (before UX); ii) the user must be able to elaborate as many feasible options as possible from GIS information (during UX); and iii) the user must be able to verify if the final choices are in accordance with the values, objectives and criteria desired by the group (end of UX). One example of information requirement to support the intelligence stage is when information comes from multiple sources: some from the end user (from social and face-to-face interaction) and others from the system (based on knowledge).

However, before defining UX requirements, the designer should analyze the user's behavior and the study context to understand whether it is viable to implement a system with such requisites. In order to do so, the designer should use the list of questions related to UXP characteristics. For instance, the definition of the user profile and context can be based on questions 4.1.1 and 4.1.2. A questionnaire can be given to DM stakeholders and results may validate potential requisites and the appropriate context to use a system in order to empower the UX. During validation, new requisites may arise, such as usability and social requisites, which may be more successfully investigated with questions presented in items 4.1.4 e 4.1.3, respectively. We provide an example of the application of the framework to validate a PGIS system that is defined with MD stakeholders (users).

When the system is being continuously used, the analysis of empowerment involves exploring how these different aspects influence the individual's perception of empowerment considering that they are (or have been) in collaborative decision scenarios. For example, the UX requirement regarding the choice phase, that was previously mentioned, can be evaluated by analyzing the empowerment aspect *User capacity building*.

This analysis can be made based on a user's social interaction within PGIS, his perception of empowerment and from answers obtained with DM stakeholders from an investigative question, such as *When is a decision achieved via community consensus*. Results may present evidence that will allow the designer to verify whether the user feels confident that the final choices he identified are in accordance with the desired preferences agreed on by the majority of stakeholders.

6 Conclusion

This works established a framework to structure an UX evaluation of personal perception of empowerment. In the example provided of its application, we showed an approach to define and validate requisites of a PGIS that support group decision-making in order to the understand user's perception of individual empowerment. In the approach, designers can use UX aspects (divided in pragmatic and emotional aspects) aligned with stages involved in decision-making regarding GIS. At the intersection of those two dimensions, the framework presents multidisciplinary investigative questions regarding user's behavior, information and interaction with GIS tools and the community in study.

Future work will consist of an empirical analysis of UX when using such PGIS to test whether the UXP characteristics related to social values of the proposed framework change based on which communities are involved in decision-making situations.

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