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Development of an inclusive Mapping Application in a Co-Design Process

Arne Vogt[1], Johannes Flacke[2], Karin Pfeffer[2], Fenna Imara Hoefsloot[2], Jane Strugar Kolesnik[3] and Johannes Schnell[1]

[1] 52°North Spatial Information Research GmbH , Münster, Germany
[2] Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, Enschede, the Netherlands
[3] Disability Studies in Nederland , Utrecht, the Netherlands

Correspondence: Arne Vogt (a.vogt@52north.org)

Abstract. Current mapping tools are often not inclusive and cannot be used by all stakeholders of spatial planning processes. In a co-design process involving scientific researchers and co-researchers with different physical disabilities, the accessibility of existing collaborative mapping tools was assessed. Based on the requirements for an inclusive mapping tool that were derived from the assessment an existing open-source software was adapted and extended to better meet these requirements. The resulting prototype of an inclusive mapping application for digital maptables was then evaluated by the group of co-researchers. The aim of this inclusive tool is to support collaborative planning processes.

Keywords. spatial planning, collaborative mapping, open-source, co-design, accessibility, participatory GIS

1 Introduction

Spatial planning and design is a complex collaborative task that should build on a common understanding and be grounded in relevant data and information. To ease this task, supportive software tools are often developed for expert users with a background in planning and GIS systems. In order to make planning more inclusive, non-experts (i.e. neither trained in urban planning nor in the use of GIS software) need to be empowered through tools to contribute their experience and perception. This explicitly includes people with disabilities, who are often forgotten in the design of digital tools (Stafford, 2022). Typical software applications that aim to support spatial planning activities are often designed for expert users. They offer a great variety of various functionalities but lead to complex user interfaces. Due to this complexity, these applications cannot be operated by non-expert users. Aguilar et al. (2020) describe the concept of a collaborative planning tool for non-experts using a digital maptable. Maptables are a suitable technology to support and strengthen stakeholder participation (Flacke et al., 2020) and have already been used for planning support systems (Pelzer et al. 2013). A current problem remains that maptables and current applications are not well-optimized for people with disabilities. Complex software is particularly difficult to use for people with physical or mental disabilities, who have special requirements for controls and user interface design. For example, users with physical impairments are sometimes unable to execute precise input patterns with a computer mouse and users with visual impairments are often unable to read small-scale map visualizations (with little contrast). Recent examples have shown that a co-design of map application works well (Rittenbruch et al. 2021, Aguilar et al. 2021, Prestby et al. 2023). However, these studies do not focus on the inclusion of people with disabilities. To make spatial planning more inclusive, there is a demand for accessible, easy-to-use software tools that can support planning processes. The applications should be tailored to the use case and limited to basic, easy-to-understand functionalities in order to be accessible to diverse citizens who are often not currently involved in urban planning processes.

In order to improve the inclusiveness of collaborative mapping tools that can assist spatial planning, a series of workshops for experts-by-experience with physical impairments has been conducted to assess how these users interact with existing software solutions. Based on these experiences, the specific requirements that mapping tools must meet to be inclusive have been derived. A co-design approach was established to collaboratively work on a prototype of an inclusive mapping application for assessing accessibility of public spaces in cities. The user groups have been strongly engaged and provided direct user feedback on issues of public accessibility to public space and on the usability of the application for people with various impairments. The prototype was primarily designed to be used on digital maptables so that several users can collaboratively and simultaneously participate in a planning task. The use of touch tables instead of traditional single-user devices also addresses another dimension of inclusiveness by encouraging true collaboration. Outputs of this study are a prototype of an open-source tool transferable to other contexts, a set of generalized design requirements for inclusive digital mapping tools, and insights into the needs and contributions of people with disabilities to make spatial planning accessible for all. The prototypical mapping application is implemented based on the existing open-source software OGITO[1] (Aguilar et al., 2021) that has been used previously (in earlier versions) in different collaborative spatial planning scenarios (Aguilar et al., 2020).

2 Co-Design Approach and Case Study

The co-design approach was carried out in the context of a case study in the Dutch city of Zwolle. It involved a group of eight physically impaired persons. The team participating in the case study comprised scientific researchers and co-researchers. The scientific researchers conducting the case study and the workshops had backgrounds in urban planning, geography, technology development and disability studies. These academic researchers were responsible for eliciting and documenting user requirements through co-design workshops with co-researchers, translating them into requirements for an inclusive mapping application, and discussing them with a team of software developers. The group of co-researchers consists of the aforementioned eight experts-by-experience with physical disabilities, all of whom live in the city of Zwolle or the surrounding area. They have diverse physical abilities: three are wheelchair users, three people have limited eyesight and two people have limited hearing abilities. All co-researchers are able to perform at least basic touch gestures on a maptable. Alternative input devices, such as trackballs or joysticks, were not used. Some of the co-researchers had experience in monitoring accessibility to public spaces for people with disabilities. Figure 1 depicts the communication between all groups involved in the co-design.

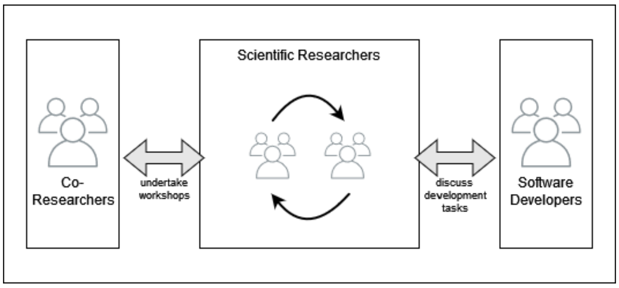

Figure 1. Interaction of scientific researchers with co-researchers and software developers in the co-design process.

The co-design process was divided into four different phases (see Figure 2). The first phase comprised a first workshop aiming to acquaint the teams of researchers and co-researchers as well as establish roles and outline the further steps of the co-design approach. In addition, the co-researchers were able to get familiarized with the controls of a maptable for the first time. In this first step a proprietary planning and spatial analysis tool using ArcGIS Pro was shown to the co-researchers.

The second phase consisted of three workshops. The main goal of these workshops was to elicit user requirements for an inclusive mapping application from the perspective of the co-researchers. During the first two workshops of the second phase it was discussed which requirements the co-researchers have for an accessible, barrier-free city and how a mapping application should be designed so that physically impaired people can use it to participate in urban planning processes that lead to a more accessible city. The second phase of the co-design was completed with a tour through the city center of Zwolle. Photographs and associated narratives were used to document examples of places where accessibility is limited or non-existent.

1 **O**pen **G**eospatial **I**nteractive **To**ol

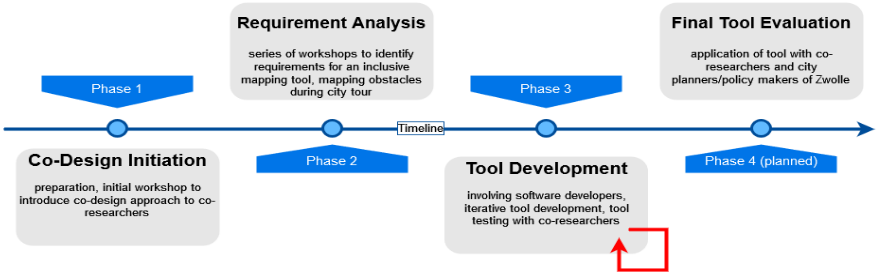

Figure 2. Overview of the four phases of the co-design process.

In the third co-design phase the original OGITO open-source map application was adapted to the requirements developed in the second phase. A team of software developers implemented these requirements. They evaluated the technical feasibility of desired modifications and new functionalities. Together with the scientific researchers, development tasks were derived from the requirements. These were prioritized according to their importance and the development effort. In an iterative process, the software developers worked on the tasks. The process comprised multiple development sprints. At the beginning of each sprint, scientific researchers and software developers determined which development tasks were to be included in the new sprint. At the end of each sprint the software developers presented the modifications and enhancements implemented during the sprint to the scientific researchers. Together, they assessed which development tasks had been completed, which still needed to be worked on and whether the prioritization of the open tasks should be adjusted for the next sprint. Another workshop concluded the third stage of the code-design process. During this workshop the co-researchers tested the adapted new version of the prototypical mapping application on a digital maptable. A basic project setup was used where testers were able to select from a few basemaps (topographic maps or aerial photos) and display some additional information, e.g. boundaries of the municipality and districts. The co-researchers tested whether basic map controls such as zooming or panning were accessible to them. The scientific researchers assisted them in performing basic mapping tasks. As with the city tour, the co-researchers documented obstacles and barriers in the city of Zwolle, but this time they were mapped in the software application on a maptable. They also provided feedback on general design aspects of the application, such as the size of control elements and text or the contrast and visibility of the color scheme.

For the fourth and final phase of the co-design the software developers will modify problems that were identified by co-researchers while working with the map application as well as implement minor change requests (e.g. adjusting the color scheme and font sizes). A workshop to conclude the final phase of the co-design process is planned. The co-researchers will use the software to map accessibility for a specific part of Zwolle together with other stakeholders (e.g. representatives of the municipality). At the time of writing this final meeting has not yet taken place.

The following briefly summarizes a subset of the requirements collected in the co-design approach that were ranked highest.

- Users should be able to map issues (can be good or bad examples) related to the accessibility in the city. To map the issues, users want to add a simple marker on the map, choose a category (e.g. traffic, noise, obstacle), add a descriptive text and annotate whether it improves or impairs accessibility.
- The co-researches liked to see the problems documented during the city tour integrated into the map and to see the photos that were taken to visualize these problems.
- A street search feature (geocoding at street level) should be added to the application for easier and quicker navigation on the map – precise panning and zooming gestures were sometimes more difficult for the user group testers to perform due to their physical disabilities.
- Since the co-researchers are all native Dutch speakers with varying English reading skills all text in the frontend of the application should be replaced with a Dutch translation.

- Several usability improvements were needed: To support visually impaired users an increased font size in map tiles and a high contrast color scheme should be used.

3 Technical Solution

The technical implementation of the prototype of an inclusive mapping tool is based on the OGITO open-source planning tool designed for use on digital maptables. During the co-design process, changes and enhancements were made to improve usability for the user group. The basic application was originally developed by Aguilar et. al. (2021). The open-source nature of the existing application framework allowed for customization and configuration. A custom map application as a the technical basis for conducting the case studies offered the advantage of being able to quickly implement enhancements and necessary adjustments.

3.1 Technical Framework

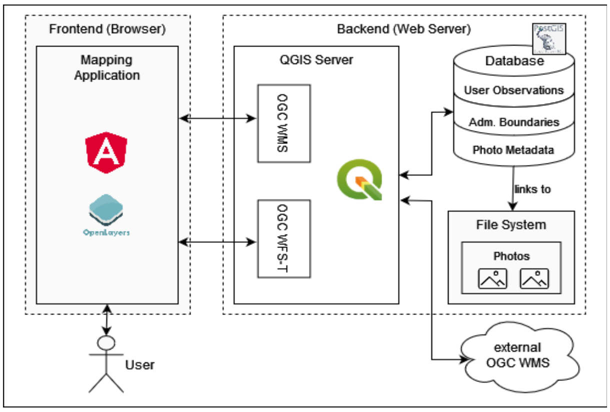

Figure 3. Application architecture based on (Aguilar, 2022) and adopted to the requirements of the use case.

The technical implementation of the existing map application is based on various open source technologies. This allows for a huge degree of customizability, avoids licensing costs and makes it easier for other developers and users to adopt the software for subsequent projects. Standardized (geo-spatial) technologies such as OGC Web Map Service (WMS) and OGC Web Feature Service (WFS) were also preferred. The application follows the basic client-server principle. The frontend is a browser-based web application while the contents of the application (e.g. visible layers, geodata) are stored and configured in the server-side backend. Figure 3 shows an overview of all components and their interactions. The client-side frontend is a web application built with the widely-used free open-source web framework Angular[2]. It also integrates multiple open-source programming libraries. The basic map interactions, map visualization and data integration are based on the open-source web GIS library OpenLayers[3]. In order to support the touch gestures needed to use maptables, the programming library HammerJS[4] is integrated into the web frontend. The core of the backend is an instance of QGIS Server[5]. QGIS Server implements multiple OGC web services including WMS and WFS. The geodata offered via the web services needs to be defined a priori in a regular QGIS Desktop project and can hence be tailored for specific planning tasks. Communication between frontend and backend works via the standardized OGC web services interfaces. To persistently store the geodata a PostgresSQL[6] database is deployed as part of the backend. The PostGIS[7] extension for PostgresSQL allows efficient storage and querying of spatial data. In general other data sources for which QGIS offers connectivity could be used to persist the application's spatial data.

3.2 Enhancements and Adjustments

The following describes the technical implementation of the key requirements identified in the co-design workshops outlined in the previous section.

In order to map an observation, users can first select its category and then choose the location on the map before adding a description as well as the date of observation. An icon (depending on the category) is then displayed on the map. The observations added in a mapping session should be able to be viewed and manipulated later in another session. To persist the mapped observations, the

2 https://angular.io/

3 https://openlayers.org/

4 https://hammerjs.github.io/

5 https://docs.qgis.org/3.22/en/docs/server_manual/introduction.html

6 https://www.postgresql.org/

7 https://postgis.net/

transactional extension of the WFS (WFS-T) was used. After users finished editing, a WFS transaction is sent to the QGIS Server backend via HTTP POST request. QGIS server persists the changes made to the features in the connected PostgresSQL database. In order to integrate the city tour photos into the map application, the image files were stored on the backend server. The paths to the image files were stored in the database along with the coordinates of the location where the photo was taken and some additional metadata. The photo locations are visualized as markers on the map. When a user selects a marker on the screen, the corresponding image's storage location on the server is retrieved via WMS *getFeatureInfo* request. The image itself is then downloaded from the server and displayed in a popup on the map view. A screenshot of the mapping application's current user interface can be seen in Figure 4 (appendix). An integrated photo is selected. The street search feature uses OpenStreetMap[8] (OSM) data. All street segments within in the municipality boundaries of Zwolle were extracted from the OSM database and aggregated by street name. The aggregated data was then imported into the PostgreSQL database, added to the QGIS project and published by QGIS Server as an OGC web service. The street search itself is implemented using WFS capabilities: When a user types in a (partial) street name a filtered (by street name attribute) WFS *getFeature* request is sent to the web service that then returns the feature(s) that match the query. The map view automatically centers on the street, which is also highlighted on the map. If the query matched more than a single street the user selects a street from the result list before the map view is adjusted. Most of the general adjustments to the user interface's layout aimed at helping (visually) impaired users (e.g. font size and color scheme) could be done by adjusting the styling (CSS) of the frontend's HTML components. The use of an open source application as the basic framework made it possible to quickly adapt it to the requirements of the specific case study in the city of Zwolle. Also, a full screen mode has been added to display the map view and control widgets only on the maptable. The full-screen mode can be switched on and off by keyboard input, because in the co-design workshops, mapping sessions were typically started/stopped by a conductor who controlled the computer connected to the digital maptable.

8 https://www.openstreetmap.org

4 Evaluation

During the workshops, the mapping application generally worked well and the co-researchers with physical disabilities were able to map observations on a maptable. However, improvements can be made on both the hardware and software side of the application to increase accessibility. The maptable, a touch screen put flat on a table, can be hard for wheelchair users to access. The device needs to be tiltable and adjustable in height. It should be also small enough to reach all corners of the screen. A solution might be to fit a simple frame around the screen so that a user can lean on it. Regarding the software, testers noted that the process of mapping obstacles could be simplified. Instead of first choosing a category by selecting the corresponding symbol from a menu, they prefer to place a marker on the map first and then opt for a category. For users with severe visual impairments, contrast and readability can be improved by switching to a sans serif font and further increasing the font size. The built-in high-contrast mode of the Windows operating systems was tested. It improved readability, but with the undesired side-effect of making some dark-colored input elements almost invisible, because all backgrounds automatically change their color to black. The color scheme of the application must be adjusted in order to work in normal and high-contrast modes. In general, many adjustments are likely to improve the usability of maptable tools for the general public with varying abilities. Simplified input schemes help users with different disabilities as well as non-expert users. Conversely, different user needs can sometimes conflict: Instead of larger text and input elements, some users prefer a better (map) overview. Therefore, there is not necessarily a one-size-fits-all solution for an inclusive planning tool. A (non-prototypical) implementation ideally provides a good degree of customizability (e.g. font size and color schemes). In addition, different users' skills are more diverse than those represented by the group of co-researchers. People with extremely limited motor skills have not yet been accommodated. In retrospect, the decision to build an inclusive mapping tool based on existing open-source software was beneficial. Requirements and change requests could be implemented quickly. The iterative development approach, divided into multiple sprints, and the resulting regular exchange between researchers and software developers fitted well with the overall co-design process.

In addition to the co-design process with the user group from Zwolle, another workshop was held with a user group from the City of Herne, Germany, consisting of people with various cognitive disabilities. Generally, the tool worked well, but it was observed that a rather limited spatial literacy (ability of reading maps) of the testers limited the usefulness of the tool (or two-dimensional mapping tools in general). A short 3D Google Street View-like visualization of a small part of the city center was what users liked most and what worked best for them. Everyone was able to navigate, describe and map routes and locations much better in 3D than in 2D visualizations.

5 Conclusion and Outlook

The chosen co-design approach has shown that different user groups have specific needs and requirements to participate in spatial planning and design tasks. For an inclusive urban planning, it is crucial to overcome the burden of traditional single user interaction and provide tools for collaborative design. In the context of this research, it was demonstrated with the prototype that it is generally possible to design urban planning tasks inclusively for people with physical disabilities. There are still (primarily technical) aspects that can be improved. The concluding evaluation of the customized software will be part of the final phase of co-design. It is also proposed to better adapt the frontend for mobile devices (mainly tablets) to allow users the mapping of obstacles on the street. Photos could be uploaded directly and afterwards experts-by-experience could use the tool on a maptable to interact with the city. There are further ideas to extend the underlying mapping tool. For example, true multi-language support is planned – for the case study, the original text in the HTML templates was replaced by a Dutch translation. This would strengthen the framework aspect, allowing new use cases to be adopted by configuration with less programming required. Integrating voice-over functionality with read aloud signals to overcome readability issues is another more advanced idea.

Acknowledgements

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Appendix

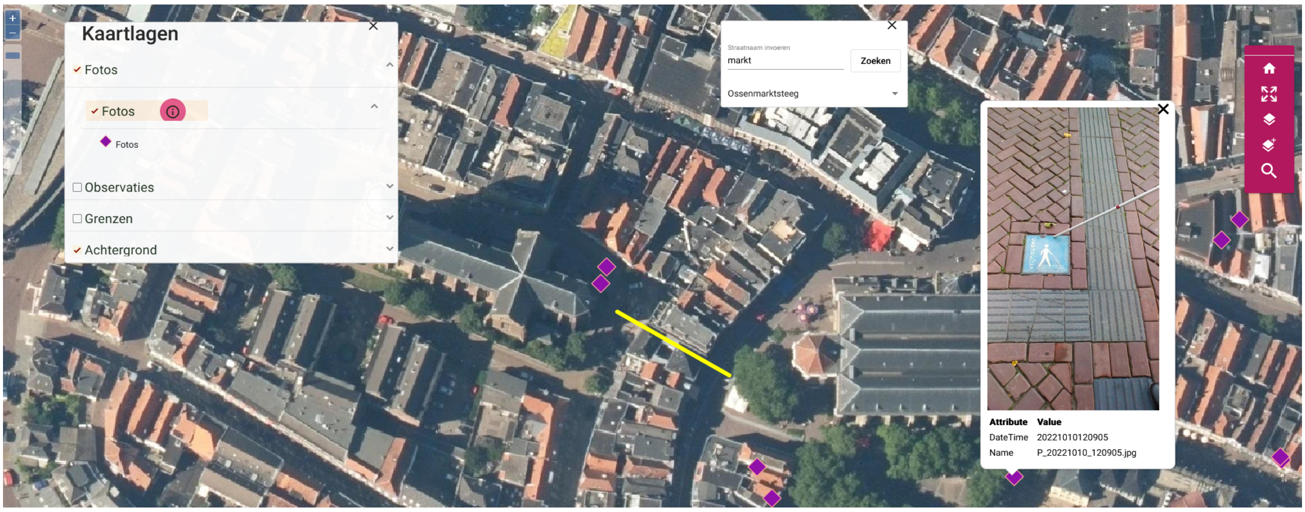

Figure 4. Screenshot of the mapping application; a photo, taken during the city inspection, is displayed and the street search is activated, background image by Publieke Dienstverlening Op de Kaart (PDOK), https://creativecommons.org/licenses/by/4.0/.