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Collaborative, Version Controlled Map Editing

by

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ABSTRACT

Geo-spatial applications, for instance, geographic information systems (GIS) are increasingly realized as online platforms. Browser-based approaches facilitate broad accessibility and thus allow collaborative work. Regarding map based editors, collaboration is in most cases done asynchronous and does not support real-time concurrent editing. Many workflows, such as gathering data in case of a disaster could however benefit from allowing multiple users to simultaneously work together on the same dataset. A browser-based map editor, called Ethermap, was developed facilitating this kind of real-time interaction supported by means for increasing user awareness, an interactive version control, a well as explicit communication about geo-objects. This work reports on implications and limitations from several evaluation methods (focus group, user study, interviews, technical evaluation) indicating the importance of facilitating user awareness, as well as an increased efficiency, which can arise through real-time collaborative map editing.

1. INTRODUCTION

Together with the notion of cloud-based computing, real-time collaboration has found it's way into many different web applications such as Google Docs, Cloud9 IDE or Etherpad[1]. Real-time collaboration describes the concept of allowing different users to simultaneously edit the same data-set while working from distinct devices. Changes made to the dataset by one collaborator are directly applied and visible to all other users virtually working together in the same editor [27]. This avoids the common process of locally editing documents, which have to be shared and merged after the necessary changes are applied. Directly working together on one dataset would otherwise only be possible by working at the same place, at the same time. As globalization continues, more and more people are collaborating from distinct locations making applications with this kind of interaction increasingly important. Overall, the field of real-time collaboration is researched very well for text-based editors showing an increased efficiency compared to standard approaches [18].

Research in the field of geographic information systems (GIS) further shows how important collaboration is when working with geo-spatial data. Balram et al. [6] define collaboration in the GIS context as a combination of theories aiming to organize the participation of groups in spatial decision processes. Users are typically both technical experts and the general public brought together through networked or distributed computers. Other authors have defined the closely related terms geocollaboration [34, 33] or group spatial decision support systems [4]. The large amount of research done in this area states the importance of geocollaboration. However, research regarding real-time collaboration in map editors is still very sparse and is only starting to appear. While first prototypes are already existing [7], a system which provides all the requirements for full real-time collaboration: concurrent non-blocking editing, means for user awareness, and version control, could not be found.

Closely related to the topic of real-time collaboration is user awareness [14]. In order to improve cooperation between different users, they have to be aware of each others actions. Therefore, features like highlighting changes, or showing the current workarea of collaborators have to be supported within the application. Another important aspect for collaboration is version control [12]. Having different revisions of a dataset makes it easily possible to revert to older versions to remove errors or unwanted changes [48]. Furthermore, knowing when and by whom changes were performed allows for a detailed inspection of the developments and thus, provides insights into data provenance [23].

Based on the previously mentioned requirements, the application Ethermap was developed from scratch as a browser-based map editor with the following research questions in mind:

- RQ1: How can real-time synchronization increase efficiency when collaborating with different users?

- RQ2: How can awareness for other users be facilitated within a map editor?

- RQ3: Which role does version control play in real-time synchronized map editors?

The content of this work is structured as follows: starting with section 2, existing work which relates to this topic is discussed. Subsequently, the overall concept of Ethermap is described in more detail focusing on the functionality, as well as the implementation. Section 4 elaborates the methodology used to answer the given research questions, followed by the actual evaluations including the results in section 5. Within section 6, the results of the different evaluations are discussed with relation to the research questions. Finally, a conclusion with a brief future outlook is given in section 7.

2. RELATED WORK

In order to create the overall concept of the proposed editor, existing literature regarding related topics was reviewed. As

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[1] `https://docs.google.com`, `https://c9.io`, `http://etherpad.org` accessed 15.09.2014

previously mentioned, important research areas for real-time collaborative editors are geocollaboration, user awareness and version control. For the implementation of Ethermap, it was also necessary to review different web-based networking techniques. Finally, existing evaluation methods for multi-user groupware were analyzed.

2.1 Geocollaboration

The need for collaborative tools supporting spatial decision making was already recognized over a decade ago by Jankowski et al. [26]. Collaboration is defined by the authors as the process of two or more persons working together on a single task. In direct comparison, cooperating means that persons are working on several tasks while only sharing the results. Use cases identified within their paper are, for example, solving spatial decision problems for urban/regional development, or land use negotiations. The actual term geocollaboration was coined by MacEachren [34, 33] describing collaboration on geo-spatial datasets from distinct places. Another related topic is given by Armstrong and Densham, introducing the concept of group spatial decision support systems [4] in which maps are used to create consensus between multiple users. The importance of map applications for geocollaboration is also given by Rinner [47] with the topic of argumentation maps. Within his research he states the need for computer supported discussions including geographic references. The notion towards collaborative web mapping was explained by Balram et al. [5] mostly through the rise of the Internet, changing the level of participation from private users to the general public. In the context of participatory GIS, these changes were also described by Elwood [16] with democratization of GIS-based decision making. However, Ellis et al. [15] state that it is important to differentiate between the four possible situations regarding temporal and spatial dimensions of participants, as they result in different kinds of interaction:

- Same Time - Same Place: face-to-face interaction

- Same Time - Different Places: synchronous distributed interaction

- Different Times - Same Place: asynchronous interaction

- Different Times - Different Places: asynchronous distributed interaction

An exemplary web-based map application for collaborative planning is described by Simão et al. [49]. Within their implementation of WePWEP (Web-based Participatory Wind Energy Planning) the authors describe how users can collaboratively plan locations for wind farms. While the application includes an argumentation map to provide means for communication as well as basic GIS capabilities, the workflow is completely asynchronous and is thus a different time, different place situation. Research regarding geocollabortion has however shown very positive effects on decision making processes when working together at a single display [35] (same time, same place). As working from the same location is not always possible, means to mimic this kind of interaction are

required through synchronous distributed interaction applications. This kind of real-time editors is discussed in the next subsection.

2.2 Real-time synchronized editors

Real-time collaborative editing systems, also called (multi-user) groupware, allow multiple users to work on a shared dataset from distinct locations. This kind of software falls into the category of computer-supported cooperative work (CSCW) [50]. Early versions of real-time collaboration systems strictly followed the WYSIWIS (what you see is what I see) principle with only one person being able to interact with the system. However, this has already been proven to be too inflexible [51]. Yang et al. [54] state that every user should be able to edit any given object at any time in order to "[...] facilitate a natural cooperative information flow [...]". A lot of research is already existing regarding code or text editors [18], but also for graphics [50], and CAD systems [40]. However, real-time collaboration for map based applications isn't researched very well. Butt and Li [7] describe a prototypical geo-conferencing tool. Their focus is primarily on the communication aspect providing video based communication and whiteboard interaction. Compared to the Ethermap approach, the presented work is rather built as a presenting/discussion tool than facilitating real editing of geo-spatial data. Thus, there are no tools available to actually edit the content of a map. As previously mentioned, in order to provide real collaboration every user has to be able to edit the data. Nevertheless, the authors provide a good overview over the research area as well as a set of evaluation criteria which could possibly be reused. A more theoretical discussion is given by Chang and Li [9] presenting an abstract model for real-time geocollaboration. Besides the technology, they also state that the combination of geo-spatial and social aspects is very important. While geo-spatial aspects include, for example, spatial data models, data queries, but also visualizations, the social aspects focus on collaboration, communication and user awareness. Even though Chang and Li included several of the concepts discussed in this thesis, their work does not rely on an evaluation using a real prototype.

2.3 User awareness

Collaboration without face-to-face interaction, strongly limits communication resources [52]. The "[...] field of view is reduced, the possibility to use gesture is limited, facial expressions are eliminated [...] and spatial co-references are difficult to resolve [...]" [8]. Research focusing on user awareness in the context of computer based collaboration has already been around for quite some time. Dourish and Bellotti [14] defined awareness as "an understanding of the activities of others, which provides a context for your own activity". Research related to multi-user editors suggest that creating awareness of other users in the workspace can drastically improve collaboration, as disadvantages arising through the lack of face-to-face communication can be reduced [30, 27]. Different methods to increase awareness are well studied for software development and text editors. Functionalities, which have already proven to support awareness are, for example, real-time highlighting of changes, visualizations of the working areas

of other collaborators, different colors for different users, as well as means for communication like chat windows [3, 24]. Overall, research evaluating user awareness in map editors could not be found. One can however assume that the previously mentioned functionalities known from text based editors could also be applied to multi-user map editors. Several of the presented awareness methods were thus adapted so that they can be used within the presented map editor.

2.4 Version control

Version control allows users to review the development of a document in order to understand decisions or to revert to a specific revision [19]. In addition to knowing how a dataset has evolved, it can be important to know who edited a specific part in order to evaluate the authenticity of the work [10]. Version control systems like GIT[2] or Subversion[3] have been around for many years to handle textual data [48] and are becoming increasingly popular as means for collaboration [12]. One example is GitHub[4], which is a GIT based online platform integrating aspects of social networks into a version control system. Regarding the aspect of text-based collaboration, this kind of revision control was already introduced several years ago [31] and is commonly used, for example, in Google Docs or Microsoft Word. However, version control has mostly been neglected in the research for geo-spatial collaboration. Currently, several prototypes are being developed such as GeoGig [5] or GitHub's diffable maps[6] allowing for storing and visualizing different versions of geo-spatial datasets. Nevertheless, scientific literature on using version control for geo-spatial data seems to be very scarce. Especially evaluations analyzing how version control can influence the mapping behavior of users within collaborative map editors was not found.

2.5 Web-based networking

Gutwin et al. evaluate different web-based networking technologies which could possibly be used for real-time groupware as for example Long Polling, XHR Multipart Streaming, IFrame Streaming, Java Applets and WebSockets. The authors discuss the necessary transfer speed for shared workspaces with telepointers, which is about 25 messages/s. Therefore, they based their study on measuring the message rate for receiving and streaming data as well as the overall network overhead of each technology. As a result, the authors showed that browser based networking technologies are in fact capable of supporting real-time groupware. Based on their benchmarks, WebSockets seem very promising showing the best overall scores [21]. Another comparison by Puranik et al. [46] state that WebSockets could transfer 215% more data than AJAX while requiring only 50% of the bandwidth. Within their paper, it is also stated that a basic TCP connection would outperform WebSockets. However, TCP is a low-level protocol which can not be used directly in browsers and

is thus not an option for this work.
Based on these evaluations, one can assume that WebSockets can be used for the synchronization of the proposed map editor. Therefore the technology is used for the synchronization aspect in Ethermap. One can further guess that transferring geo-data would require an even less frequent update rate as mentioned by Gutwin et al., as no fluid movements, such as mouse cursors, have to be synchronized.

2.6 Evaluation Methodology

Based on a survey paper about groupware evaluation by Pinelle and Gutwin [45], it was shown that evaluating multi-user systems has already received a large amount of attention. The authors state that seven main evaluation methodologies were used for various studies: user observations, interviews, discussions, questionnaires, qualitative and quantitative work measures, as well as collections of archival material. Nevertheless, it was pointed out that previous evaluations mostly focused on individuals instead of considering the increased complexity of real-time workflows with multiple concurrent users [41, 45, 2]. Neale et al. [41] identified several main factors besides cognitive aspects of individual users, which have to be evaluated for multi-user systems: "[...] cooperative and collaborative factors, usability issues for individuals and groups (ease of use, effectiveness, efficiency, satisfaction), the social and organizational impact, and the larger context that situates the other factors". This was also recognized by Gutwin and Greenberg [20], who claim that usability challenges are often occurring through poorly implemented collaboration activities. Within their concept of the "mechanics of collaboration", they explain that "[...] these activities [...] are the small-scale actions and interactions that group members must carry out in order to get a shared task done", such as, communication about tasks or the monitoring of other collaborators. Thus, CSCW systems should be evaluated using multiple users simultaneously [41, 45, 2]. This was also shown for offline group collaboration in the context of participatory mapping by Aditya [1].

An exemplary user study procedure to evaluate real-time collaboration is given by Butt and Li [7]. Starting with a pre-questionnaire they try to analyze the participants background as well as their computer and GIS expertise. Subsequently, an actual interaction with the system provides the opportunity to log the users interaction with the application in order to gain insights into their usage patterns. The last step is based on another questionnaire focusing on usability, interactivity as well as the graphical user interface.

Besides this kind of user-centric evaluation, Damianos et al. [13] state that multi-user groupware should also be evaluated on a technological level to gain insights into the systems performance and costs, as well as through expert reviews to receive opinions of end-users. Neale et al. [41] also state that multiple evaluation methods should be used in combination "to balance shortcomings with any given approach".

Regarding Ethermap, the presented literature shows that several factors are necessary to assess the quality of a system. Compared to single-users applications, not only usability and performance have to be evaluated, but also cooperative and

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collaborative aspects. To cover all of these aspects, a combination of multiple evaluation methods is advised.

3. CONCEPT

In order to answer the research questions proposed in section 1, the application Ethermap was developed facilitating real-time synchronization of geo-data between map clients. In the following, the overall functionality of the application is described. Afterwards, the used technologies and the implementation are discussed.

3.1 Functionality

Existing research showed that collaboration is a highly interactive process in which participants iteratively contribute their thoughts [53] to a project. Current applications allowing for collaboration on geo-spatial datasets (e.g. Open-StreetMap[7]) are created based on an asynchronous communication, requiring clients to manually reload updates. Thus, changes made by one user are not directly visible to other collaborators. This prevents a natural collaboration behavior, which is why this kind of application is often used when working together over a larger period of time. If changes are applied on an outdated client, conflicting states can occur, which can often not be resolved automatically.

However, many use cases, such as disaster mapping, require multiple collaborators to work together simultaneously. Applications, such as the OSM Tasking Manager[8], try to prevent conflicts by allowing only one user to edit a particular map location through locking the region for all other collaborators. Nevertheless, existing research showed that real collaboration is only possible if every user is able to edit any object at any given time [50, 54].

The map editor Ethermap was developed as a new application, aiming to solve this challenge for geo-spatial data. Ethermap allows for creating, editing and deleting simple geometries, such as points, lines and polygons. These geo-objects are commonly called features. As previously mentioned, the main concept of the proposed editor is based on the idea of virtually working together on the same dataset. Therefore, every time a feature is created or edited, changes are directly transferred to the server, stored in a database and pushed to all other clients. Figure 3 shows this basic process in a simplified diagram. Through integrating this kind of synchronization into a map editor, different users are always working on the same dataset, allowing collaboration without locking currently edited areas. Other synchronous alternatives are, for example, screen-sharing, where map content is transmitted via video, having the disadvantage that only one person is capable of editing the map. In addition to that, transmitting a video stream produces a large amount of network traffic and is thus not very efficient.

Inspired by research regarding text-based editors [3, 24], several means to create user awareness were integrated into Ethermap. For instance, when updating changed features within the map, an unobtrusive visual highlighting is applied: the outline of a particular feature is displayed with another

color for a few seconds before slowly returning to the original style. In order to create awareness about who performed an action, every user is represented with a different color. In addition to that, a list of all currently connected collaborators allows users to know, who else is working within the same map.

Research further showed that it is important to know, where on a map collaborators are currently working [28]. Compared to text editors, it is not sufficient to show a single cursor in a document to indicate where someone else is working, as geo-objects are at least two-dimensional. Therefore, displaying the workarea is done by shortly highlighting the map bounding box of a particular user as a rectangle on the map. This rectangle is also drawn in the user-specific color. After a short amount of time, the rectangle disappears to avoid overloading the map with too much content. It is further possible to "watch" the viewport of another person. This means that every map movement (zooming or panning) of the watched person is mirrored to the own map, allowing a user to see the same map content while still being able to interactively control the map. Watching other users could be used as a means for remote presentations, or by new editors trying to learn from more experienced users. Both, showing and watching viewports can be done for all users simultaneously, or for individuals. Furthermore, toggling the edit mode of a feature, which happens by clicking on an object within the map, is also synchronized between all clients. If several persons are editing the same object, they will be informed about the other users working on this feature. This should reduce surprises, which could occur if a feature is suddenly changing while a users is about to apply his own edits.

In addition to user awareness, establishing means to communicate with other users in the map is a requirement to collaboratively solve tasks [30]. Especially in geo-environments, objects often do not have a meaningful name, making a verbal description very complicated. Explicitly referencing objects within the map can thus enhance conversations [11]. Therefore, a chat was integrated into Ethermap, including the possibility to reference features within chat messages. References are displayed as little icons displaying one of the three geometry types: points, lines or polygons. Figure 2a shows a referenced polygon within a chat message. By clicking on the polygon icon, the map automatically centers on the particular map location, mimicking a simple point-gesture, which would be used when working together at the same screen. References can be included into a chat message by clicking the "Refer to feature" (cf. figure 2a) button, which allows to select a feature by simply clicking on it in the map.

Especially when working together with multiple users, it is important to get an overview over the performed work. Within the application, a continuous history feed provides information over the changes made to the map. The history states whether geometries or properties were added, changed or deleted. The feed itself is represented as a list, where subsequent actions of individual users are aggregated to avoid cluttering the history. A map history including aggregated list items is displayed in figure 2d. Clicking on a list entry will result in the map directly centering on the particular feature.
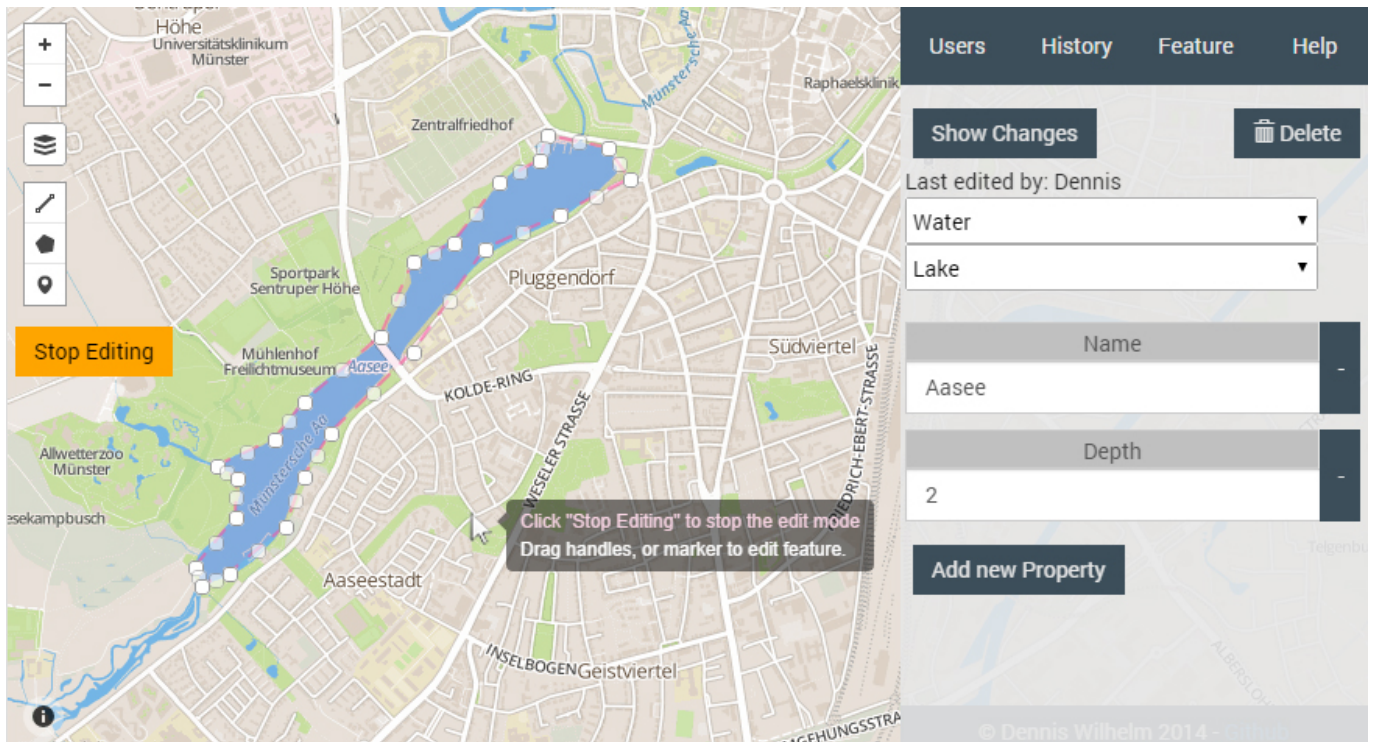
Figure 1: Screenshot showing the complete application Ethermap. Map view on the left with a polygon in edit mode and contextual menu on the right showing the properties of the feature.

Therefore, the user will know which feature was described in the history. In addition to the overall map history, a more detailed overview is available for individual features. An interactive version control system was developed to review the revisions of a feature. Different revisions can be shown using either a slider or by clicking through the "older" and "newer" buttons, as shown in figure 2c. Changed feature properties are color-coded based on the type of the change. New attributes are colored in green, changes in yellow and deleted attributes are displayed in red. Changes made to the geometry are directly visible within the map, allowing for a context aware review of the developments. Compared to the color approach of the textual attributes, the geometry revisions are displayed within their original style, as the color is already defined by the features attributes. For instance, buildings are colored in red. In addition to reviewing older versions, it is also possible to revert a feature to a previous revision. Reverted features are directly synchronized between all clients.

As known from OSM, every feature can be categorized and described with an unlimited amount of attributes. For Ethermap, the existing category system of OSM[9] was reused. Within this system, features can be classified in order to describe geo-objects based on informal standards. Exemplary categories are: buildings, landuses, railways. The style of a feature defining the representation within the map (colors,

line-width, etc.) is automatically generated from the chosen category. For example, polygons which are categorized as "building" are colored in red. Choosing from these categories results in corresponding input fields within the graphical user interface. For instance, buildings have an address and a number of levels, whereas roads provide, among others, an attribute for the speed limit. Furthermore, users can append custom properties (key/value pairs) to extend the default fields. These attributes are also synchronized, if changed by a user. Figure 1 shows an exemplary polygon in the edit mode with drag handles to change the geometry of the feature. On the right side, the properties of the feature are displayed within a contextual menu. In addition to that, it is possible to see the last user who edited the feature.

A short video demonstrating the functionality of Ethermap is also available on YouTube.[10]

3.2 Implementation

Previous sections already identified fast data gathering, decision support, presentations and discussion of geo-spatial data as possible use-cases for Ethermap. Considering a broad audience based on public participation with non-experts, requirements are low hardware requirements but mostly easy accessibility. Throughout the last years, the performance of web browsers has drastically increased, mainly due to hardware acceleration and faster JavaScript engines making desktop-like web applications possible for the first time [21].

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[9] **http://wiki.openstreetmap.org/wiki/Map_features** accessed 28.08.2014

[10] **https://www.youtube.com/watch?v=ByRp-g3egLk** accessed 28.08.2014

(a) User tab displaying users currently online and the chat. Shows buttons to watch users, show their workarea and refer to features.

(b) Feature tab showing the attributes of a feature and provides input fields to edit them.

(c) Individual feature version control. Allows browsing through revisions with a slider and buttons. Displays changes and provides means to revert to a specific revision.

(d) Summarizes actions on the map in list form. Subsequent changes of users are aggregated to avoid a cluttering of the list.
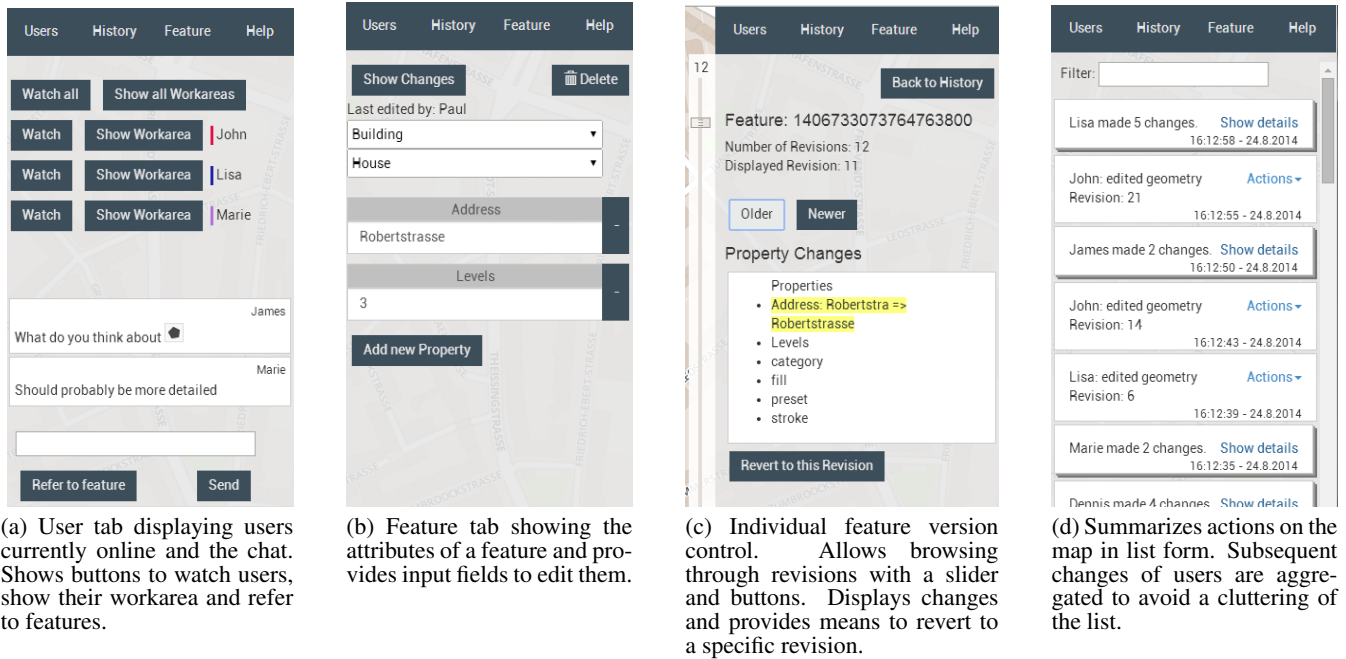
Figure 2: Different contextual menus available within Ethermap providing access to the user list, map history, feature properties and feature history.
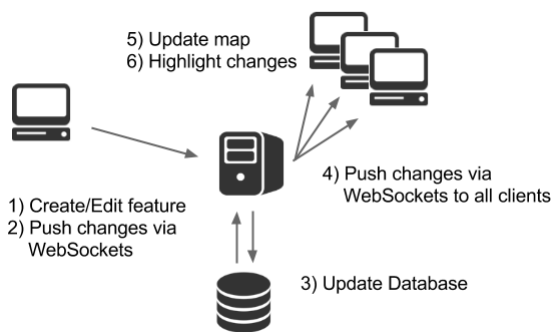

Figure 3: System architecture including the synchronization sequence. Features are created on the client, transferred to the server, stored in the database and then pushed to all other clients.

Therefore, the decision was made to implement Ethermap as a web application. As the application is completely based on HTML5 and JavaScript, access to the editor is provided via a common web browser, without the need to install any additional programs or plugins. Keeping entry barriers as low as possible was identified as one of the main challenges for open collaboration [39]. By making the application accessible throughout a common web browser, collaborators can access Ethermap from almost any computer. Even though many map editors are already existing, for instance, iD[11] of OpenStreetMap, the application was developed from scratch. This decision was made to be more flexible, as the editor

could specifically be designed for this purposed without having to adjust the workflow to fit an existing framework. The development was performed in an agile manner with early feedback from employees of the university, students, friends and family in order to recognize usability problems as well as missing functionalities. The development took about three months full-time programming. The complete program code is available as an open-source project on GitHub[12]. The following subsection describes the implementation of the client and the server in more detail.

3.2.1 Server

For the server backend, node.js was chosen as it uses an event-based loop resulting in a non-blocking I/O server, which requires less resources compared to multi-threaded servers. This makes node.js well-suited for WebSocket applications which rely on a high amount of concurrent client-server connections.

As already mentioned in section 2.5, WebSockets provide very good means to establish real-time connections. As a WebSocket library, socket.io was chosen as it is an open-source node.js module providing automatic protocol switching for older browsers without WebSocket integration. By changing the connection to XHR/JSONP polling the synchronization can be used in a wide variety of different browsers. Data is transferred as JSON objects. For geo-objects, the widely adopted community standard GeoJSON[13] is used.

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[11] **http://ideditor.com/** accessed 13.09.2014

[12] **https://github.com/dwilhelm89/Ethermap** accessed 28.08.2014

[13] **http://geojson.org/geojson-spec.html** accessed 13.09.2014

The data is stored within CouchDB, which is a NoSQL database operating on JSON documents. CouchDB is built as multi-version concurrency control database. This means that there is no database lock allowing multiple write processes at the same time. Especially when working with several persons on the same dataset, this can be very important. To handle concurrent write processes, CouchDB stores every update of a document as a new version keeping the previous versions accessible with an unique revision id. Therefore, data is not lost even if multiple users update the same document. An important aspect is that CouchDB is "eventually consistent" focusing more on data availability and fast access than absolute consistency. Other databases are often built on the ACID principle, where every transaction is handled atomic resulting in blocking read or write processes. To summarize, CouchDB provides very good means for write-intense applications combined with a basic document revision control.

Several alternatives for the data storage were considered. Other popular databases as PostgreSQL or MongoDB were discarded, as they don't provide a built in version control, even though a PostGIS database would be better suited to handle geo-data. As no complex geo-related computations are required for the prototype, having the built in version control was more important.

In the field of software development, the most popular version control system is probably GIT. However, GIT is not built for fast read/write processes and gets very slow if the repository size increases. Two other approaches, which could be investigated in the near future are Dat[14] and GeoGig[15]. Both are currently in an early alpha stage and have therefore been rejected for Ethermap. Dat is specifically designed for high frequent database updates (real-time data) including version control. GeoGig focuses on distributed versioning of geo-spatial data. A downside of both systems is however that Dat and GeoGig are not built as databases and thus do not provide query capabilities.

Research for real-time text editors suggest using "operational transform"(OT) [27] algorithms to synchronize the state of several clients. In OT only the actual changes are transferred with a reference, where the changes have to be applied within the document. Compared to text documents, map features are atomic objects with an unique ID. Therefore it was sufficient for the prototype to simply transfer complete features as Geo-JSON. This reduces the complexity of the synchronization and prevents state conflicts, which can occur if a change message are lost or received in the wrong order. By always sending the complete object, the application will be functional at every time.

3.2.2 Client

The client side implementation was built with a simple and clean user interface in mind. In order to provide the discussed functionalities (cf. section 3.1), the following technologies were used. As an overall framework, Angular.js was chosen to provide the functionality to easily extend and modularize the code base. Establishing the WebSocket connection was done, as also on the server side, with socket.io.

For the map interface, Mapbox.js was chosen which is built upon the popular open-source map library Leaflet.js. Both have a very active community and are widely used in the web. The decision for Mapobox.js was based on the integration of the simplestyle specification[16] allowing features to be rendered with regards to their GeoJSON properties thus facilitating an easy style synchronization.

4. METHODOLOGY

In order to answer the proposed research questions from section 1, several steps were performed.

At first, the functional requirements for the application were established based on literature describing real-time collaborative editors from other domains (cf. section 2). Within the reviewed publications, means for user awareness and version control were already identified as important aspects of such systems. Therefore, several methods to increase user awareness as well as a basic feature version control were adapted from text-based editors in order to be used within map editors (cf. section 3). Subsequent to the functionality assessment and the design of the overall concept of Ethermap, the choice of technologies and eventually the implementation followed.

As the review of the related work revealed, different evaluation methods are available to assess the quality and usefulness of real-time, multi-user applications [45]. However, all of them have shown certain shortcomings, which is why it was pointed out that combining several methods to evaluate a system could be beneficial [41, 13]. As a conclusion, four different evaluating methods were chosen to evaluate the concept and implementation of Ethermap:

- Technological Evaluation

- Pre Study + Focus Group

- User Study

- Expert Interviews

Based on the bottom-up approach by Damianos et al. [13], the evaluation started by assessing the overall feasibility with regards to the chosen technology. This was especially important, as a well-functioning application was a requirement for the subsequent user-centered studies. As Ethermap is based on a client-server architecture, the actual connection between both parts, as well as the server capabilities are the most crucial factors when evaluating the systems performance in terms of scalability. This is why the technological evaluation focused mainly on the speed in which data could be transferred via the WebSocket streams, as well as on the database speed for reading, writing, and updating data. In order to interpret the results of the server performance, the speed for rendering GeoJSON objects within the map was also analyzed.

For the evaluation of usability and user awareness (RQ2), a user study was conducted. Starting within a pre-study, the given use case and task for the actual user study (described below) was tested. The pre-study was split into two parts: a practical task combined with a questionnaire, and a focus

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[14] **http://dat-data.com/** accessed 15.08.2014
[15] **http://geogig.org/** accessed 15.08.2014

[16] **https://github.com/mapbox/simplestyle-spec** accessed 28.08.2014

group discussion. The results of these evaluations were used to check if all required information to answer the research questions could be gathered from the prepared study. Within the focus group, general feedback about the prototype was collected. Unsatisfactory parts of the user study, as well as of the prototype itself could therefore be adjusted.

Within the actual user study, multiple users were tasked to simultaneously map a specified area. Gathering the required data for the evaluation was done, as also tested in the pre-study, via questionnaires. In addition, a logging mechanism stored all user interactions to analyze the usage behavior of the participants. The procedure for this user study was based on the publication by Butt and Li [7] with the small modification that the pre- and post-questionnaires were combined into one single survey in order to simplify the process.

For both studies the use case of disaster mapping was chosen, which usually describes the aim to update maps after a disaster has struck [55]

Three different map layers were used in Ethermap, which could be selected by the participants at any time. An aerial image as well as an OpenStreetMap layer served as base maps showing current map data. The third layer contained near-infrared images after a flooding from Germany[17] (2013). By switching between the different layers, it is possible to recognize flooded areas. Figure 4 shows an exemplary area with two different map layers. Based on the near infrared image (left) it is possible to distinguish between vegetation (red) and water (greenish). In comparison with the aerial image on the right the flooded meadow can be recognized, which would also be colored in red if it had not been flooded.

Based on these map layers, the task for the participants was to collaboratively map areas, which were affected by the flood. The original OSM feature attributes (cf. section 3.1) were adjusted within Ethermap in order to provide new categories for flooded or blocked areas and lines. In addition to that, POI categories for damage and possible meeting points were created. These changes were inspired by the *Deichgraf* project[18], which was a successful example of disaster mapping by citizens.

Whereas the user study focused on usability and user awareness, interviews were used to gain insights into opinions of domain experts [13]. Three interviewees were chosen from the fields of disaster management, GIS, and web-mapping. in order to assess the overall usefulness of real-time, synchronized editors for geo-spatial data (RQ1), but also to evaluate the interactive version control for geo-objects (RQ3).

5. EVALUATION

Several evaluation methods were used to answer the proposed research questions. Starting with a technical evaluation, the feasibility of the application was analyzed. User-centric evaluations followed throughout a focus group, an user study, and expert interviews.
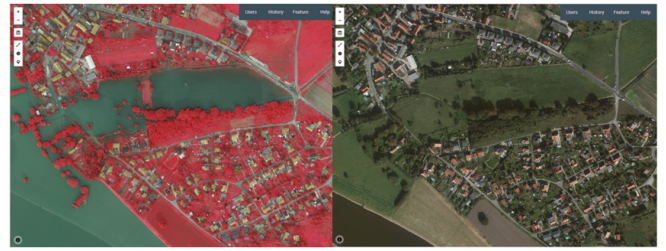
Figure 4: Image showing the same map extent with two different layers. Near infrared image after a flooding on the left and current satellite imagery on the right. The greenish area on the left depicts water while red indicates vegetation.

5.1 Technical Evaluation

Evaluating the application is important, as all following user-centered studies are only possible with a well functioning software [13]. The following subsection describes the evaluation of Ethermap via its implementation focusing on feasibility, performance and scalability.

5.1.1 Methodology

Existing literature has shown various measurement factors to assess the performance of real-time synchronized applications. For multi-user systems built with client-server architectures, the connection between client and server is one of the most important parts, as a fast synchronization between all clients relies on this connection. Especially, the number of messages per second distributed between all clients [21], which is defined as the maximum throughput [46], allows the analysis of the connection performance.

As a first step, default message sizes for the main synchronization actions (editing features, viewport changes) were calculated providing insights into the data volume, which has to be transferred between client and server. Synchronizing features requires sending their representations as GeoJSON strings including the complete geometry and properties. Therefore, 10,000 buildings of a German city were exported from OSM from which the mean storage size was calculated. Buildings were chosen, as they usually provide the most complex geometries and are therefore a pessimistic consideration of the required message size compared to point or line features.

Another evaluation aspect was the amount of concurrent users the system can handle. Therefore, several test scripts were developed, allowing to connect a chosen amount of clients to the server, distributed across multiple computers. Each client simulated a real browser by connecting to the WebSocket streams of the server. Clients randomly emitted one of the three commands for feature edits, map movements or chat messages. The number of clients was incrementally increased until the server load was too high and the messages could not be received by all clients anymore.

By measuring the WebSocket round-trip time (the time required to send a message to the server and receive an answer), the maximum transfer rate can be determined. For the test, 10,000 messages were sent repeatedly while measuring the time. All measurements were performed in a LAN to

Table 1: Summary of the results of the server performance evaluations.

Measurement	Value
DB write speed (documents per second)	235
DB update speed (documents per second)	48
DB read speed (documents per second)	329
Number of WebSocket messages per second	1,600
Number of active concurrent clients	300
Features drawn on the map per second	1327

reduce network latencies. For all messages, a dummy payload of 100 bytes (i.e. the size of a GeoJSON point) was used. As shown in figure 3, every change is stored within the database before it is distributed to the other clients to keep the dataset consistent. In order to evaluate the complete dataflow between client and server, it was also necessary to evaluate the insert and update speed of CouchDB. This was achieved by several custom test scripts. To eliminate HTTP transfer times, documents were inserted directly on the server, without any network connection. Measurements were: the time required to insert 10,000 documents (same ones as used for the WebSocket tests) as new documents, inserting new revisions for existing documents, and reading documents. Based on the previous database tests, it was easily possible to compare the storage size of the database for single documents and for documents with multiple revisions. All measurements were based on a test environment using an Ubuntu 12.04 virtual machine with 2GB RAM and three Intel Xeon cores at 2.66GHz.

In order to set the server side performance evaluations in relation to the clients perspective, the speed to render GeoJSON objects was also measured. As in the previous tests, 10,000 GeoJSON points were used as a sample size. The test started with the pre-loaded features as the network connection should not be included within this evaluation. For the actual evaluation, the time to draw all features on the map was measured. Compared to the default Leaflet operation, this test also included custom functionalities of Ethermap, as for example, visually highlighting changes.

5.1.2 Results

The first step was the analysis of the bandwidth requirements based on the WebSocket message sizes. When zooming or panning, clients need to send the working area to the server. It is defined by two coordinate pairs for the north-east and south-west bounds (14 decimal places per coordinate), which can be encoded as a JSON string of 120 bytes. The mean storage size for OSM buildings in GeoJSON has been calculated with an average size of 308 bytes (SD: 196 bytes). The next step of the evaluation was to measure the capabilities of the server. Table 1 summarizes the results.

Regarding the WebSocket connection, an average of 1,600 messages per second was measured. Without any interaction the server was further able to handle up to 8000 clients before new clients could not connect anymore. However, this did not include any actual interactions between client and server that would normally occur. Therefore, this kind of test is not suitable for real-time synchronization editors. To create actual server load, different events were simulated on the client side

(for example map draws, map movements, chat). The current implementation (without any load-balancing) was able to handle up to 300 of such clients concurrently without errors. Beyond that number, the amount of packet losses and disconnects rapidly increased to unusable levels.

The time required to insert 10,000 documents was measured with 235 documents per seconds. Creating new revisions was substantially slower as multiple requests have to be handled: 48 documents per second could be processed. Reading from the database was possible at 329 documents per second. For retrieving revision data, 269 documents per second were possible. Within these tests, the documents had consecutive ids. Due to the way CouchDB stores documents on the disc, reading performance can vary substantially if retrieval keys are far apart from one another.

CouchDB stores data (individual documents, revisions, deleted documents) as JSON documents. Storing 100,000 individual GeoJSON markers (each 80 bytes) resulted in a storage size of about 320 MB. 1,000 GeoJSON markers with each 100 revisions (also 80 bytes) resulted in a larger storage size of about 433MB. Storing revisions thus requires more space than storing individual documents. As revisions are not always needed, CouchDB offers the possibility to compress the database by removing everything except the latest version of a document. In the previously mentioned test with 1,000 features with 100 revisions per feature, the disk space decreased from 433 MB to 1.2 MB.

In addition to the server side performance tests, the speed in which features can be rendered within the Leaflet maps was measured with 1,327 features per seconds. However, after drawing 10,000 points on the map, the performance of the application (e.g. zooming, panning) decreased substantially. Overall, the client is very lightweight consisting only of about 600 KB for custom JavaScript and HTML code combined. Including third-party libraries and configuration files, the initial page requests sum up to about 1MB divided over 27 individual HTTP GET requests.

5.2 Pre Study + Focus Group

Getting feedback about the implemented application, as well as to testing the designed user study were the main reasons for conducting a preliminary study with a focus group session. This section describes the used methods, as well as their results in more detail.

5.2.1 Methodology

Reasons for using a pre-study and a focus group discussion, but also the procedure of the evaluation are discussed within this subsection. In addition, participant demographics are described.

Participants:
During the focus group session, 13 candidates (9 male, 4 female) participated with an age ranged between 25 and 34 years. All of them PhD students from various fields of research having a geo-related background.

Procedure:
Starting with a presentation of about 10 minutes, the participants were introduced to the overall topic, as well as to the task for the practical session. After that, a time frame of 15

minutes was reserved to perform the previously mentioned task of mapping flooded areas (cf. section 4). The main reason for the practical task was to create a basic familiarity with the application, which was required to establish the foundation for the subsequent discussion. In order to simulate working from different locations, the participants were instructed not to talk to each other in "real-life" during the practical task. The main part was the focus group session, which took about 30 minutes. Focus group discussions rely on active group interactions instead of following strict question-answer procedures providing the possibility for spontaneous discussions, which can often not be anticipated when planning topics for a discussion [43, 44]. Therefore, focus groups are good means to evaluate early prototypes, where unspecific input is desired. Research shows that participant numbers of about 6-12 persons seem to be most efficient [38].

To analyze the focus group, the discussion was recorded and transcribed using anonymized names from P1 to P13. Based on the transcript, a combination of a discourse and conversation analysis was used to evaluate the discussion. Within the first method, individual representative statements are extracted out of the discussion and analyzed in detail. In addition to that, group response and conversation patterns (conversation analysis) were used to evaluate opinions of other participants about the statements.

5.2.2   Results

During the discussion, several main challenges for real-time synchronized editors were identified. One issue, which came up several times, was that it was unclear how to behave if someone else was editing the same feature or features nearby in the map. P1 mentioned: "If I tried working on something and someone also mapping the area - It confused me, so like - should I continue to work or should I stop?". As a feasible solution the idea came up to create some sort of "collective agreement"(P3) describing how to behave in certain situations where conflicts with other users might occur. Another proposal to enhance collaboration was, to facilitate requesting help at specific locations. This should lead to explicitly call users to collaborate within a given area.

A large discussion topic was based on the collaborative workflow in general. One participant stated that it could help to assign different roles to users: "One is doing the rough geometry, so that when you log in you say: I am doing the rough geometry and I don't care if it's accurate. And the next person is doing details and the next one is doing validation."(P12). This could even be practiced in some sort of use case specific, informal training before starting the editing process.

In addition to that, a feature request for giving short descriptions about the applied changes was made, "[...] because we don't know if someone changed a feature because of an error or mistake"(P1). This should help to understand why certain changes were applied to the map content.

As a general statement regarding the given task, it was mentioned that providing examples on how to map flooded areas would help inexperienced mappers. Examples should explain how to recognize flooded areas and in which level of detail they are supposed to be mapped. Regarding examples, P3 mentioned: "One should see an example of some work.

Maybe even fake a user who's fame is something like superpro and everyone can look: That is the level of accuracy for which I should aim at least. And if you see rough polygons you know if it's acceptable".

During the practical task, the chat was not used. This was explained by some participants due to the simplicity of the task, as "[...] everybody probably just took an area and started tagging somewhere [...]"(P8).

Overall nobody mentioned any issues regarding usability or problems of the existing functionality.

5.3   User Study

As previously mentioned, a user study was conducted with the goal to evaluate usability and user awareness aspects of the application. This section describes the methodology used to conduct the study, as well as the results.

5.3.1   Methodology

Within this section, the procedure of the user study as well as basic participant demographics are described. In addition to that, the post-study questionnaires are discussed in more detail.

Participants:

The 39 participants for the user study were students of geoinformatics, geography and landscape ecology, which had used GIS software before without having any use case specific knowledge. 17 of the participants were female, 12 male and ten didn't want to state their gender. The participants age ranged from 18 to 26 (mean = 20.6, SD = 1,7).

Procedure:

Similar to the user study by Butt and Li [7], a combination of logging user behavior and questionnaires was used to gather the data for the analysis. The user study was performed with two individual groups consisting of 20 and 19 participants, each with the use case described in section 4. Each session started with a ten minute presentation describing the task. As the pre-study had revealed a lack of information on how to find flooded areas, the introductory presentation provided the participants with an overview on how to use the different map layers to solve the task. In addition to that, the functionality of Ethermap and its editor tools were presented. Subsequent to this introduction, the participants were asked to start the application by entering a previously assigned, random user ID. Within Ethermap, a click-through tutorial shortly repeated the task and reminded the users about the main tools. As all participants were placed in the same room, "real-live communication" was prohibited to simulate working from distinct places. After 15 minutes of mapping, the application automatically switched to the online questionnaires. This was the most effective way to get opinions from all participants [32]. In addition to the time and cost factor, online questionnaires are considered to be more private and less intrusive compared to face-to-face interviews [32]. For the user study, a custom logging system was implemented to record all interactions with the system. These include, for example, opening the different contextual menu tabs, showing the workarea of other users, or simply zooming or panning within the map. All of these logs were also send to the server in real-time and stored in an individual database. By inserting the user ID from the

practical task into the survey, map actions and questionnaire results could be analyzed in combination.

Questionnaires:
The questionnaires for the user study were carried out as an online survey, which started automatically after the practical task was finished. To gather different information aspects, the survey was divided into three parts. At first, terms of the questionnaire were explained within a short introductory text. Following this, general information about the participants as age, gender, and expertise with geographic information systems were captured together with questions about previously used real-time synchronous editors. The second part of the questionnaire focused on the functionality of the editor with regards to the three main concepts: real-time synchronization, user awareness and version control. Exemplary questions for those categories were, for example, if the presence as well as changes of other users could be recognized, or if the actions of other participants interfered with their work. Overall, this survey section consisted of 12 questions which had to be answered on a seven point Likert scale (from "strongly agree" to "strongly disagree") with alternating directions. Eight questions were free text fields and seven questions were supposed to be answered as single-choice questions with "yes", "no" or "don't know". The third section of the questionnaire consisted of four questions of the Nasa TLX [22], which was included in order to gain insights into the perceived workload of the task, based on subjective ratings of the factors: mental demand, performance, effort and frustration. The questions had to be answered on a scale ranging from "low" to "high" with 20 different points on a scale. Only the performance scale ranged from "perfect" to "failure". Questions for physical and temporal demand of the original Nasa TLX questionnaire were omitted, as they were not applicable for the study. All questions were written in German.

Free text answers were analyzed by categorizing the responses based on the given statements, for example, reasons why a particular feature was, or was not used. By assessing the quantities of answers in a particular category, the importance of individual statements could be analyzed. Questions based on the Likert scale were analyzed by calculating the frequency of the given responses as they come from an ordinal scale were parametric statistics can not be applied [42]. Even though the used seven point Likert scale provides a higher granularity, the results were simplified for the analysis. Therefore, positive (e.g. "strongly agree" and "agree", etc.) and negative answers were combined in order to reduce the scale to a three point Likert scale consisting out of the options: agree, neutral and disagree. While the original data provides more information about the magnitude of the answers, the simplified version "requires considerably fewer responses " [36] while still providing acceptable data. This method is therefore especially useful when analyzing smaller sample sizes.
A few questions of the survey were ignored, as the corresponding functionality of Ethermap was not used during the user study. These included, for example, questions about the usefulness of the feature version control.
The most common way to analyze the Nasa TLX questions

is by weighting and aggregating all measurements of a single task into one number [22, 17]. As only one task was evaluated during the user study, this approach is not applicable. Therefore the responses are analyzed in comparison with the remaining questions of the survey. As the results are based on an ordinal scale, median and standard deviation are calculated to obtain an overall tendency of the results.
In order to check for possible linear relationships between individual questions, a common analysis is to check for correlations between question pairs [37]. Therefore the a Pearson correlation analysis was performed, which required to code the Nasa TLX (1 - 20) questions, as well as all questions on the seven-point Likert (1 -7) scale into numerical values. Subsequently the correlation coefficients were calculated for all question pairs. In addition to that, t-tests were used to validate the significance of the analysis.

5.3.2 Results

Based on the performed user study, two different datasets were gathered: the logged interactions and the questionnaire responses.

Logged Actions:
During the user studies of both groups, 268 features (93 lines, 10 markers, 141 polygons) were created with a total of 972 revisions. This means that every feature was edited an average of 3.95 times. The revisions can be split up into 268 feature creations, 24 feature deletions, 344 geometry editings and 336 property editings. Figure 6 depicts the actions performed by the different users showing that the activity level was very different. Four participants were very active and performed over 55 actions compared to the average 24.9 actions. Three users applied almost no changes to the map.
29 of the created features were edited by two or more participants. Out of these, 23 features were edited by two individual users, five features were edited by three different users and only one feature was edited by six individual users. Even though features were edited a total of 972 times. The "edit mode" has been activated 1677 times. The edit mode of a feature is started by clicking on a feature to open its attributes or to edit the geometry. This implies that 705 times, users only looked at a feature without applying any changes. Table 2 summarizes the amount of users toggling the edit mode for the same feature. While most of the features (202) were only selected by their creator, 25% of the features were selected by more than one person. One feature was selected by eleven different users. Figure 5 shows the development of a feature, which was edited by six individual participants. Based on the timeline it is possible to see when a user was in the edit mode (blue bars) and when changes were applied (red ticks). At one point, users 49, 77 and 26 were concurrently editing the same feature, while user 50 only watched the feature for a longer time, without performing any actions.

Besides the actual mapping tools, the "User" tab was opened 113 times. While reviewing this tab, the "Watch User" functionality was used 20 times. "Watch All" was used nine times and the "Show Workarea" button was clicked eleven times. Furthermore the "History" tab was opened 84 times. While, the history of individual features was opened seven times, the
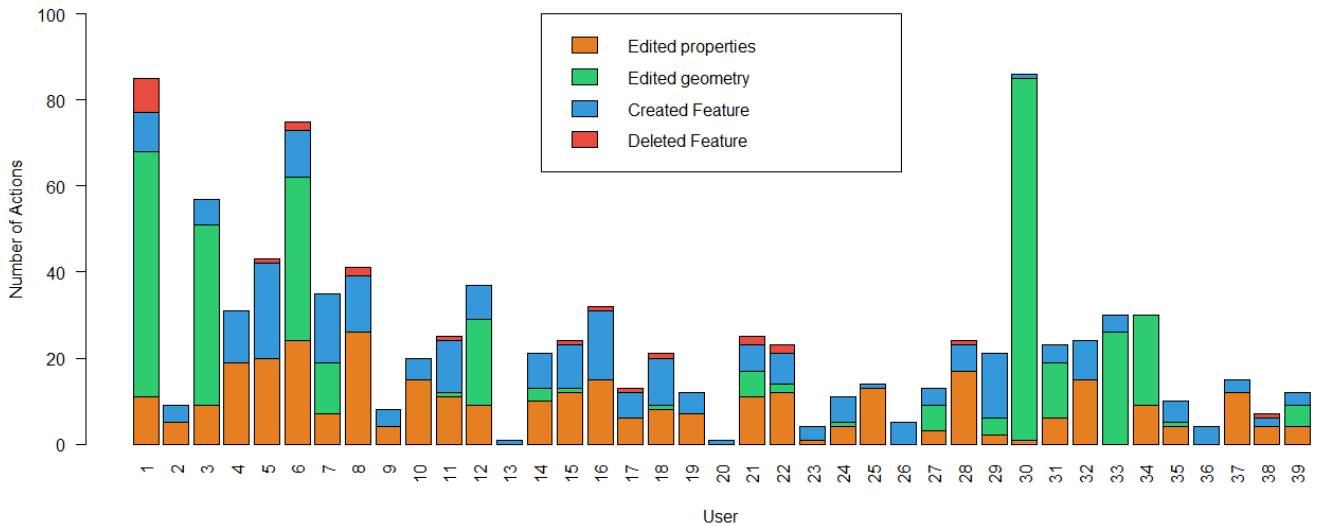
Figure 6: Histogram summarizing the number of logged actions performed by each user divided into the four categories: edited properties, edited geometry, created feature and deleted feature
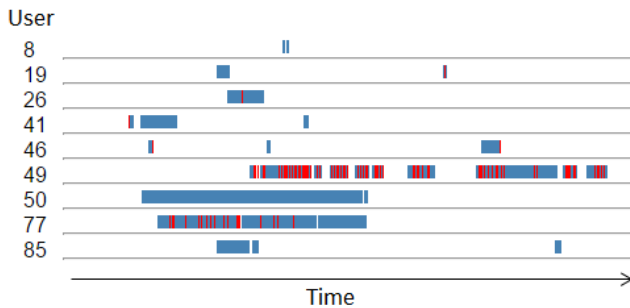

Figure 5: Chart displaying the actions performed on a single feature by different users. Blue bars indicate if the feature was in edit mode, red bars indicate an actual edit/change. Each row displays a corresponding participant.

Table 2: Table summarizing by how many users a feature has been viewed in edit mode.

Amount of users	Features
1	202
2	43
3	7
4	10
≥ 5	6

functionality to revert features to older revisions was not used. Furthermore, the tutorial was used 53 times.

Overall, 19 chat messages were sent by 9 individual users. Four of those messages contained a reference to a feature within the map. Reasons for using the feature referring tool were, for example, asking if a polygon was marking a flooded area. Therefore the feature was integrated into the message to point other users directly to the questioned feature. Another participant referred to a feature to convince the other collaborators to edit an already existing feature instead of creating new ones. One participant asked the group why the river was marked as flooded, too, by including a feature reference to the question.

During the time of the study, the participants zoomed/panned a total of 10353 times.

Questionnaire Results:

The questionnaire started by asking the participants about their overall experience regarding geographic information systems, as well as about previous usages of real-time synchronized editors. 19 persons (49 %) rated their experience with low to no experience at all. Eleven participants (28 %) selected medium and the rest rated themselves with a good or expert experience (9 participants, 24 %). Out of these participants, 27 (69 %) had never used real-time synchronized editors before. Three candidates (8 %) were unsure and nine persons (23 %) used this kind of editors before.

As previously mentioned, one of the main research questions was to evaluate user awareness within Ethermap. The questionnaire reveals very positive results, as 31 participants (80 %) stated that they could recognize the presence of other collaborators very well. Five users (13 %) responded with a neutral answer and only three users (9 %) claimed that they couldn't recognize the presence of other users. Answers to the question if changes by other users were easy recognizable showed similar results. 70 % (27) of the candidates gave a positive feedback to this question, 28 % (11) could not recognize changes by other users and one user (3 %) responded with a neutral answer. Based on a free text answer, participants could state by which functionalities they could recognize actions of other users best. The most frequent answers were, highlighting with colors, direct appearance of geometries within the viewport, but also through the history view. Even though the visual highlights seemed to be important, 15 persons (38 %) had a neutral opinion about the question, if the colors helped identifying which user performed an action. The remaining 24 participants (62 %) were evenly distributed in agreeing and disagreeing to the statement.

Regarding the question, if users were annoyed by the actions of other users, the answers are distributed very even. 31 % (12 users) seemed to be annoyed by the actions of other users, 33 % (13 users) had a neutral opinion and 36 % (14 users) stated that they were not annoyed by other users. Another question addressed this question in more detail by asking if the highlighting of changed features was annoying. Seven participants (18 %) agreed to this question, ten (26 %) had a neutral opinion and 22 candidates (56 %) disagreed to the question. When being asked, if someone stopped editing an object because another person currently editing the same object was recognized, 20 candidates (51 %) negated the question. 16 participants (41 %) stated that they stopped working on an object because of other concurrent editors and three users (8 %) were not sure.

Another section of the questionnaire was based on the communication aspect of Ethermap. When being questioned about why the chat was (not) used in a free text answer, the most common answer was that there was no need to communicate for the given task. The few people who used the chat stated that it was used for asking or answering questions about the task. According to the questionnaire results, the "refer to feature" tool was used to ask questions about a specific geometry without having to explain the area with a lot of text. Other statements mentioned that the tool was used to spare collaborators from searching for the mentioned feature. Answers regarding the "Watch" and "Show Workarea" indicated that most users did not use the functionality to look at other collaborators. It was also stated that the "Watch All" tool was very confusing based on the high number of changes from different persons.

A more general question was based on the speed in which the editor could apply the changes to the map. While 33 participants (85 %) were satisfied with the speed of the editor, only 6 users (15 %) had a neutral opinion on the speed or were not satisfied. Very positive answers were also given to the question if a revision history is useful in a map editor. 32 participants (82 %) agreed to this question, while only 6 persons (15 %) had a neutral opinion and only 1 user (3 %) disagreed. In addition to that, 27 persons (79 %) believed that the task could be done faster through the applied real-time synchronization. Seven users (18 %) were unsure and five persons (13 %) disagreed.

To evaluate the subjective workload, four questions from the Nasa TLX questionnaire were used. The mental demand of the task was assessed with an median of 8 (SD=4.5) showing that most participants rated the task as not very demanding. Performance was rated with an overall median of 10 (SD=4) describing a neutral opinion. The question regarding personal effort resulted in a median of 6 (SD=3.8), which is a rather low effort. Finally, the personal frustration was rated with a median of 10.34 (SD=5.1), which is also a neutral opinion but with a larger distribution. A histogram displaying the frequency of the individual responses is given in figure 7. As shown in the figure and also by the calculate standard deviations, the range of the answers of mental demand, performance and frustration are distributed almost among the complete range of the scales.
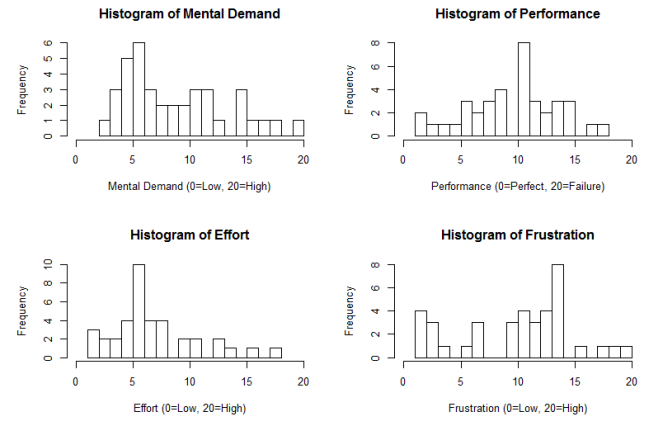
Figure 7: Histograms displaying the frequency of the individual Nasa TLX responses

The last section of the questionnaire was based on free text answers focusing on which functionalities of Ethermap the participants liked best, or which they liked the least. Most positive statements were about the actual synchronization, the chat, but also regarding the simplicity and good usability of the editor. Rather negative statements were mainly that working could get confusing if there were to many collaborators in the same area. In addition to that, the global revision history was described as complicated.

The correlation analysis resulted in a moderate linear relationship between the Nasa TLX questions for mental demand and effort with r = 0.6 (p <0.0001). Other question pairs didn't show relevant correlations. A matrix showing the correlation coefficients between all question pairs is displayed in table 4. The values range from -1 to 1, where values near 0 are not correlated. A value of (-) 1 represents a perfect correlation.

5.4 Expert Interviews

As a final part of the evaluation, interviews were used to gather insights into the opinions of domain experts. The following subsection describes used methodologies and results of the interviews.

5.4.1 Methodology

While the user study mostly focused on answering aspects about user awareness and usability, interviews were used as they provide a good means to get insights into the subjective perspective of domain experts [25]. The focus of the interviews was based on the general usefulness of the Ethermap concept, but also on individual functionalities, for instance, the interactive feature version control. Compared to other survey types like questionnaires, interviews provide the most flexible means, allowing to use more complicated questions, as the interviewer can directly react to the respondents answers [32]. By using semi-structured interviews, a set of guiding questions was used to keep the survey going while allowing enough space for open discussions or other statements of the interviewee [25]. A set of questions used for the interviews is given in Appendix B.1.

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The following experts were interviewed:

- Albert Remke (I1), CEO of 52° North GmbH and innovation manager at Esri Deutschland Group GmbH and founder of con terra GmbH

- Kate Chapman (I2), executive director at the Humanitarian OpenStreetMap team - working in the field of disaster management; previously involved in the development of web-GIS applications

- Christian Elfers (I3), Head of Product Management at con terra GmbH - working in the area of web-GIS development

All interviewees were contacted via an e-mail, which included a short introduction of the topic. All sessions started with a demonstration of Ethermap. Subsequently, the semi-structured interviews were conducted, each taking about 30-40 minutes. In order to allow a detailed analysis, the conversations were recorded and transcribed, following the transcription rules of Kuckartz et al. [29]. The main essence of these rules are that the transcription is done verbatim without summarizing the content. In addition to that, filler words, such as "hm" are omitted. Punctuation can be adjusted towards the style of written language.

Based on the physical distance, one interview was done as a Skype interview including screen sharing to present the demo while the other two were performed as face-to-face interviews. For the third interview, a video demonstration of Ethermap was used, as no Internet connection was available.

Analyzing the interviews was done using a category system [29] in which the statements of all interviewees were aggregated based on different factors. Categories used for this "coding" process were, for example, questions about the overall concept of Ethermap, the interactive feature version control or methods regarding user awareness. Based on these categories, a direct comparison of the interviews could be made in order to analyze the opinions regarding the individual questions.

5.4.2 Results

Based on the presented application, all three interviewees responded with a very positive feedback regarding the overall concept of a real-time, synchronized map editor. I2 responded that for doing similar things, screen-sharing would be used, where only one person would be able to control the map. I3 agreed, mentioning that many problems as, e.g., disaster management are currently not addressed very well based on the missing aspect of real-time synchronization. Another important aspect, mentioned by I3, is the technological barrier, which is very high when using desktop sharing approaches, but drastically decreases through a browser based approach.

When questioned about the efficiency when working simultaneously together, I1 responded that given the right scenario, the concept of Ethermap could definitely increase the productivity of all collaborators. Nevertheless, both I1 and I3 agree that this could be very use case specific. I1 further reports that real-time collaboration is only meaningful, if all persons "are in the same context and [...] have a similar understanding of

what has to be done". I2 agreed that real-time synchronization allows users to work better together, as usually editors have to include other mechanisms to prevent users from colliding with each other, which often results in restricting users. Besides the given use case of disaster management, possible areas, which could benefit from a real-time synchronization, were identified by the interviewees as, for example, teaching, planning, logistics, but also tourism, and helpdesk applications. When asked about the current functionality of Ethermap and the integration of more complex GIS capabilities, I1 and I3 agreed that this is very use case specific. I1 reported: "I think it's a very good idea to start with these simple features and then extent if necessary. So keep it simple as far as possible". However, it was also pointed out that measurement tools (I1), as well as simple analysis as, for example buffering could be helpful in discussions (I2). Other feature requests were for example the need to get a quick overview of the existing attributes in the map. I2 reported: "One feature I think would be useful, would be some sort of spreadsheet to view the attributes available for the features in an area". Overall, I1 and I2 agreed that many functionalities of a collaborative editor would probably benefit a lot from spatial filters. Examples would be the map history, feature attributes (I2), but also the user list (I1), which could be filtered based on the current map viewport (I2).

Questions about user awareness resulted in very positive feedback. I1 already asked if it was possible to know if other users are online, before the user list was shown within the demo. I1 also mentioned the importance of knowing where on a map other collaborators are currently working, and how active they are, to get insights into their current focus or interest. I2 also stated the usefulness of user awareness methods and related the functionalities to positive experiences, which were already made when collaborating in GoogleDocs. I3 agreed that it is important for people to know that they are not working alone on a topic. As shown in other areas, as for example, how many people are currently reading a certain article. Being able to see how many users are working on the same task would also imply some sort of importance (I3). Besides methods to increase real-time user awareness, I1 also mentioned that reviewing the activity on a timeline could be beneficial in order to know how the focus of the work has changed over time, or how up-to-date data is.

However, allowing communication within the editor seemed to be one of the most important aspects for all interviewees. "[...] I thought chatting about a specific object was really cool as well. Because it is an easy way to point them at an object if you had specific questions about it"(I2). Even though I3 stated how important communication is, he explained that chatting is often only the first step, whereas a communication via voice would be even more beneficial.

Another aspect covered in the interview was the interactive feature version control. I2 reported: "Especially when you have new editors. Having an easy way to go back, and one: show the mistakes, and two: correct mistakes instead of redoing the work, you could just go back in time." In addition to that, I3 stated that especially in real-time scenarios, where people are working under time pressure (e.g. disaster management), errors will occur. Having an "undo" tool is

therefore very important. I1 also mentioned: "to see what has happened to a feature and to see how it was edited, if it was refined somehow, or when did it pop up?", is very important.

6. DISCUSSION

The conducted evaluations provided several insights into the systems performance, participant's user behavior, and also into opinions of domain experts. This section discusses the results of the evaluation methodologies, divided into the different aspects: technology, real-time synchronized map editors, user awareness, version control, and limitations.

6.1 Technology

Several conclusions can be drawn from the technical evaluation. Most importantly, it demonstrates that real-time collaborative map editing is technically feasible and scales well using web technologies on standard hardware. The results indicate that up to 300 concurrently active clients can be supported at speeds well above the recommend 25 messages per second [21].

While the evaluation is subject to some limitations, it still provides evidence for the scalability of the approach. Within the implementation, the main bottlenecks were the database and, to a lesser degree, the number of WebSocket connections. Essentially, the number of simultaneous users depends on their activity profile, network properties, and the server capabilities. Regarding the activity profile, random selections of possible actions were chosen, which were executed by the simulated clients. A more realistic approach would be to record actual interactions of real users and use those for an evaluation. Basic performance could easily be enhanced by improving network bandwidth/latency and increasing server resources (e.g. SSDs instead of HDDs, more RAM and CPUs). It would also make sense to test the database performance using bulk operations for inserting/updating datasets. In addition, all server parts (database, node.js server) could be deployed as cluster systems, allowing a load balancer to distribute users across multiple servers.

The speed, in which the client is able to render new features on the map, has further shown that the client would not be a bottleneck in the architecture, as features can be drawn faster as they can be inserted into the database. One can further assume that the measured 1300 features per second would probably not be required in normal scenarios. Even though rendering features is very much hardware dependent, it should be considered that several thousand features can not be handled by the browser without a substantial loss in performance. If an even faster update rate would be required, one could omit the highlighting of changes to speed up the rendering process.

6.2 Real-time synchronized map editing

Evaluating how real-time synchronization can increase the efficiency of geo-spatial map editors was one of the main research goals. Based on the questionnaire results, participants thought that the task was done more efficient through real-time collaboration. Interviews with domain experts also resulted in very positive feedback about the Ethermap concept. All interviewees stated that they believed in a potentially increased efficiency through the synchronization aspect. Although, they pointed out that benefits depend on the use case,

as not every scenario profits from this kind of collaboration. All respondents liked the idea of an easy to use editor with only a limited amount of functionalities. Nevertheless, the interviews revealed that different use case could also require different tools and would therefore benefit from a detailed requirement analysis.

Based on the user centered studies, one can assume that the overall functionality and the general concept of Ethermap were easily understandable, as all participants were directly able to start mapping after the introduction. Furthermore usability issues were not brought up during the discussion or within the questionnaires, which is why one can conclude that the editor can be used intuitively.

The logged interactions further showed that 29 of 268 features (9 %) were edited by more than one person. The example (cf. figure 5) showed that at some point a feature was edited by several users at the same time. Over 25% of the created features were selected by multiple participants. Although one does not specifically know, if the features were actually reviewed by the users, the possibility for this kind of group work in such a short time would not be possible without a real-time synchronization. Without any previous division of tasks, the participants implicitly organized themselves and chose unmapped areas to work on. Overall, their collaboration was mostly on a macro scale, meaning that missing geo-objects were created instead of refining already existing features of other users.

The overall scores of the Nasa TLX question regarding mental demand shows that the task was mostly rated as not very demanding. This means that the task of the study was probably easy understandable and that the editor could be used intuitive without much thought. However, the subjective opinion regarding performance shows that most of the participants were not completely satisfied with their own work. As the overall effort was also rated as rather low, it is possible that the task was maybe too easy, which would also factor into the low mental demand scores. Compared to the previous three questions, responses regarding the frustration level of the participants were distributed the most. It could be possible that some participants were distracted by too many changes made by other persons within the map. The correlation analysis showed that there is a moderate correlation between mental demand and effort. According to that, participants stating that the task required a low effort also had a tendency to stated that the task was mentally rather less demanding. Participants reporting a high effort therefore also claimed that the mental demand was high. Even though the t-tests reveal that the correlation coefficients are statistically significant, the correlation is not very strong and has thus to be interpreted carefully.

Many topics, which came up in the focus group and in the expert interviews did not specifically target real-time collaborative editors for geo-spatial data, but rather real-time synchronization and collaboration in general. Challenges as how to coordinate users within a shared workspace or how to behave if other persons are editing the document nearby do also exist in editors for graphics or texts, proving that this is still a very relevant research topic.

Regarding the initial research question (RQ1), the most benefits when using real-time synchronized editors can be

achieved when multiple users are actively working at the same time. As shown in the user study, users iteratively worked on features within a matter of seconds. Furthermore, participants were automatically able to distribute their work without creating conflicting datasets. This kind of actively working together would not be possible without real-time synchronization.

6.3 User awareness
RQ2 asks, how user awareness can be facilitated within collaborative map editors. Results of the user study show that the majority of users was able to recognize both, the presence of other collaborators, as well as changes others made to the map. In addition to these basic statements, the questionnaires reveal that several persons stopped editing a feature, which was currently also edited by someone else. This confirms the previous statements regarding the recognizability of other users. One can only assume that this increased user awareness prevents potential conflicts, as it helps users to be conscious about the fact that they are not working alone. The actual awareness seemed to be created mostly through highlighting of changed features as well as the direct updates of the geometries within the viewport. Nevertheless, using different colors did not result in an increased awareness regarding which user performed the actual changes. In addition to that, the functionalities to show the workarea of others or to watch their actions were used only sparsely. However, this could be due to limitations of the user study. As the study anonymized all participants by using random user IDs, the users did not know to which user the ID referred to. Another hypothesis is that a connection between colors and users can only be established by the users, if the number of collaborators is smaller. The number of users is definitely important regarding the "watch all" functionality. User who used this tool stated that it was very confusing as too many changes were occurring simultaneously.

The importance in facilitating user awareness was also stated by the expert interviewees. All of them responded with a very positive feedback and stated that it is very important to know who else is currently working within the map. As mentioned by I1, knowing where most users are currently working on implies some sort of importancy of a particular area. In addition to that, it can provide insights into the currency of the dataset. Although, the watch tool was not used very often within the user study, I2 mentioned that the tool could be used for teaching or presentation purposes. Regarding the aspect of communication, especially I1 and I2 liked the possibility to talk about individual map features within the chat, being an easy way to ask questions about specific features or to point collaborators to a certain location. I3 however reported that voice chats would in some cases even be more valuable. Within the user study, the chat was used sparsely. However, several questions based on existing map features were asked and could successfully be answered by other participants.

Overall, the implemented functionalities to create user awareness worked very well. Regarding RQ2 it could be shown that the adaptations and extensions methods from existing text editors, could help users to recognize the presence and actions of other collaborators. Especially visual highlights and the direct appearance of changes helped to recognize changes. Knowing if other users are online, and knowing where they are on a map, seemed to be very important means for facilitating user awareness. Furthermore, communicating via chat messages, especially with references to map features, proved to be an important functionality.

6.4 Version control
Even though the map history was only used moderately with an average of two times per user (85 times in total), the questionnaire results revealed that a map history is useful. The version control for individual geo-objects was not used during the user study. This was maybe due to limitations of the user study, as the participants started on an "empty" map, were everyone simply started mapping to cover the area as fast as possible. Based on the limited time frame, the users probably edited features directly when mistakes were recognized instead of taking the time to go through the feature history and find a revision to revert to. As all participants of the user study were new to the topic, reviewing the data and analyzing the mapping quality was perhaps not as important to the users as creating new features. Other tasks, e.g., collaborating on planning processes could result in different usage patterns. Nevertheless, opinions gathered during the interviews showed the importance of having a version control mechanism. While the participants in the user study simply used the application to create the dataset, the questioned experts focused more on the overall concept. Regarding RQ3, the statements of the expert interviewees showed that version control is maybe not very important in the actual mapping process. Responses, such as "to see what has happened to a feature and to see how it was edited, if it was refined somehow, or when did it pop up?"(P1), or, "especially when you have new editors. Having an easy way to go back, and one: show the mistakes, and two: correct mistakes instead of redoing the work, you could just go back in time."(P2), reveal that possible use cases are rather in data analysis/ refinement, or teaching.

6.5 Limitations
The user study was performed with students having only little experiences with GIS systems and almost no domain specific knowledge about disaster mapping. Especially for evaluating communication aspects, means for watching other users or showing the workarea of collaborators, the anonymity of the participants could have been an obstacle. It is unclear, how different group sizes would affect the outcome of the study. As only one task was used, possible changes when using Ethermap for different scenarios were not evaluated. In addition to that, based on the limited time of the user study, it was not possible to recognize possible changes in the user behavior over time. In order to analyze the efficiency of real-time map editing, a direct comparison to an asynchronous application would be beneficial.

The technological evaluations were mostly based on the overall feasibility of the approach instead of comparing different technologies for the best performance. Furthermore, all evaluations were based on simulated tests instead of using real users.

7. CONCLUSION

The given work described the concept and implementation of Ethermap. Based on a combination of several evaluation methods, different aspects regarding synchronization, user awareness, and version control were analyzed in order to answer the given research questions.

The technical evaluation showed that the chosen approach using web technologies for a real-time synchronized map editor is technological feasible and results in a good performance. Future improvements could be done by distributing the server load on a cluster network using a load balancing approach in order to allow more concurrent users. In addition, database write processes could be enhanced by using bulk operations. Nevertheless, the given implementation meets all requirements for the given concept and runs very stable.

The overall concept of a real-time synchronized map editor showed promising results in the user study as well as in the interviews. It was shown that workflows for various use cases, which rely on multiple users, could be improved by applying the Ethermap approach. Scenarios identified during the evaluations were, for instance disaster management, teaching, and planning.

Furthermore, functionalities adapted from text-based editors regarding user awareness have proven that they can also be very efficiency in a map editor. Especially highlighting changes and providing a list of active users seemed to help recognizing the presence and actions of other collaborators. In addition, the interviews showed that getting to know where other users are within the map could have a positive impact on collaborative work. Watching other users was not used very often during the user study, but received positive feedback from the domain experts in the context of teaching or presentations. Communication was identified as an important aspect of Ethermap. Especially allowing discussions with a reference to geo-objects seemed to be very useful

Integrating version control mechanisms into a map editor did not receive much attention during the user study. However, insights from the interviews showed that having different revisions as well as a map history could be important for quality management or data analyses.

Given the right context, real-time synchronized map editors can thus increase efficiency when working together with multiple users.

Our study was subject to several limitations. In order to provide even more insights into the usefulness of Ethermap, different use cases, such as using maps for presentations or urban planning could be analyzed in future work. Other factors not considered within the given evaluations are, among others: different group sizes, task complexity, and expertise of the participants. Therefore, the concept of Ethermap still provides several areas which could be approached in the future.

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Appendix A. CD-ROM

Content:

- *ethermap*
  Program code of Ethermap including client and server side code.
- *evaluation*
  Questionnaires including results
- *media*
  Images and video of Ethermap

Appendix B. INTERVIEWS

Appendix B.1   Interview Questions

Overall concept and functionalities:

- Do you use existing synchronous online collaboration tools like: Google Drive, Etherpad, Microsoft Live, etc? If yes, for which purposes?
- What do you think about the overall idea of a real-time editor for geo-spatial data?
- Which of the presented functionalities do you like best or worst? And why?
- What do you think about?
  - map history
  - interactive feature version control
  - highlighting of changes
  - watch functionality
  - show workarea
  - refer to feature + chat
- To what extent do you think real-time synchronization can improve workflows?
  - especially for geo-data?
  - geo-data compared to textual data?
- Could you imagine using the editor for remote presentations of geo-spatial data by using the "watch" tool?
- Which use cases could you think of where real-time synchronization could increase the efficiency of map editors?
- Where do you think could it be helpful to have a version control for features?
- Do you think real-time synchronization would also make sense for more complicated GIS applications (e.g. GIS analysis, buffering, intersections, etc.)? If yes, which features would you like to see supported within the editor?

General map usage and workflows:

- What is your/ your users approach for storing different versions of geo-spatial data?
- What is your/ your users approach to share maps/ geo-data?
- What is your workflow when multiple parties are involved?

Appendix B.2   Transcribed Interviews

Appendix B.2.1   Dr. Albert Remke

[Computer shows two browser instances of the Ethermap landing page] I: I've started the recording and (...) what you can see here [shows to computer] are two browser windows opened on the same page and I have the possibility to choose a map name - for the application as well as a user name. And I'm just going to type in 'test' for both browsers [types the map name into both browsers] and we are landing on the same page. And with two browsers we are basically representing two different clients. The overall idea of the application is a real-time synchronization. So every action between the different clients is directly synchronized between all clients.

I1: So may I ask. What is the use-case?

I: Today I'm more or less going to focus on the application itself. So, what are the main functionalities. I guess, the functionality is more or less use-case unspecific. But for my thesis I chose the use-case of disaster mapping. So I had a user study were I had a WMS layer containing information about floodings in Germany - With the possibility to switch layers which is here [shows the layer switch tool on the computer] basically a default functionality of maps. One could recognize floodings and the task of the students was to map those flooded areas. But today, I'm - more or less going to focus on the overall functionality and the concept which could also be applied to different use-cases. Different use-cases could be for example - urban planning. So different geographers for example could use the tool to (...) to get to a common understanding of a planned routed for example. Or a planned street. Did that answer your question?

I1: Yes. So the background of my question is (...) are we dealing with (...) dynamic phenomena - for example - in the context of disaster management - flood plain would be very dynamic and it could change over the day for example.

I: The overall idea is always to work together with multiple people on one dataset and therefore the main reason is probably to (...) get data together really fast. So multiple persons working on dataset which - (I1: so crowdmapping) - yes crowdmapping - basically enhancing the process of creating geo-data which would normally be done with different users working on their own dataset which would have to be merged afterwards.

I1: So people know that they are working on the same topic. But there are no agreements - before entering into the process regarding who is doing what (I: yes). They don't know each other. But can they see who is editing in the map?

I: Yes, there is a list of all users [shows the user list in the application]. Currently there are only two users. Dennis1 and Dennis2 - and you could up a an unlimited amount of users as far as the server would manage this capability. And of course it would probably make no sense if there would be 1000 persons editing in one area. Because it would probably to much edits (...) to recognize. Maybe it would be chaos. But with a few people like it is for example done in tools like Google Docs, where you can edit a text together, I guess it makes sense.

I1: I don't know if I should continue to ask questions?

I: Yes, why not. No it's totally fine.

I1: I would follow your structure if you want to. (...) Ok so, I know that there are further users working on the map. They are active in the sense that they are logged in - I don't know if they are really active and doing certain things at a certain moment or is there an indicator where I see that people are doing something. So for example the order of the names of the participants is changing. Or it is highlighted if there is an activity?

I: It is possible to display where a user currently is. So we have this "Show Workarea" button [shows the tool on the computer] which displays the current extent and you can do that for all users. So you can directly recognize areas where persons are possibly working on.

I1: So show workarea is my workarea?

I: No, the workare of the person [shows the username on the computer]

I1: So I would select one of the persons, one of the people which are online and say I would like to see the workarea of this person.

I: Yes, and by doing that you can basically recognize, where a person currently is on the map and - if I'm before in a different location you will directly be panned to that location. And that's just to see where persons are currently working. The other possibility is to watch persons - and that is basically the possibility to follow all actions of a user. So if one person is panning or zooming [activates the watch tool for a user and starts panning on one map. The other map automatically changes the viewport] the other person is synchronized in the viewport. And I guess this could be especially helpful for presentations were one wants to show what he has done or wants to make a certain point and other persons could just watch the person. And to recognize actions, there is a highlighting. So if a feature changes [drags a marker in one browser. The marker updates automatically in the other browser and is highlighted with a blue color] it is shortly highlighted with a color and as you can see...

I1: I didn't get this. So you can place a marker (...) what was the activity?

I: I just changed the position of a marker and it is highlighted for a short amount with a color. And the same would apply also for maybe a polygon. If I change it, another person in a different browser would see a color highlighting. So the outline was shortly in a different color.

I1: So you are working in the left window? [shows to the computer]

I: Yes, I'm trying to simulate different users. So that would be maybe one user [shows to one browser windows] and that different person [shows to the other browser window] would just be in the same viewport and would see: Ok, the color has changed, here was a visual effect.

I1: So this was a new feature? The point marker is a feature you (...)

I: Yes, so you basically can create polygons, lines or markers. If I create a new marker it will also directly be show up within the different window. And as you can see here the outline color was blue [shows the highlighting on the map], and that is also the color assigned to that user.

I1: So what I didn't get is - did you change the mode of - your window? This left window, before you entered this new marker?

I: No.

I1: You just used that tool on the left [shows to the marker tool on the computer]?

I: Yes. You can directly start mapping and use all the tools. Or you can just click on a feature and it's in the edit mode.

I1: So you are always in the edit mode and you start it by clicking the tool.

I: Yes exactly. And every user has a different color assigned. So here we have a light green, and that user is green [shows the user list in both windows and points to the user color]. And if I would change a feature on that side [edits a feature in one browser] the color would be green. So if you have different users, every user has a distinct color. And therefore, when different persons would be editing on the same viewport, you could possibly distinguish that there are multiple people working on. So we have the synchronization, showing workareas, - watching users - which are basically the - functionalities for synchronizing the features and the overall functionalities I guess. Other parts would be, as know for example from OpenStreetMap, that every feature has of course a set of categories. So polygons can have different categories than markers [clicks on a marker and on a polygon and shows the categories in the contextual menu] for example a polygon can be a building, can be land-use or water. And each one has a set of sub-categories. So a building can be for example an apartment or a residential building. And (...) so we have all the main functionalities to start mapping and create new features and assign context to those features. And of course, I could simply insert for example here [shows to the fields of a feature in the contextual menu] we have a building, which is a house, and I could start entering an address just as a text [inserts a text into the textfield].

I1: One question, watch all and show all workareas would zoom out?

I: Yes. It would make sense if there would be multiple persons - or even more persons involved in the map. So If I had for example five persons and would hit "Show all workareas" (...) I could just show you [opens a third browser window]

I1: So in the case that it is a worldwide application it would automatically zoom out?

I: To all users. So, let's zoom here a little bit out [changes the map location of all three browsers]. So you can basically see we have now two users here and if I now hit "Show

all workareas" [nothing happens] (...) Ok sometimes we still have a few bugs. It should zoom to both workareas.

I1: So. But in general you would zoom out?

I: Yes. In general you would zoom to both of those regions and (...) like - that you can see all workareas. And - this could be helpful if you really want to know which areas are worked on and you could either choose: there are already persons working on that space - I'll choose a different one. Or I'll join them and we could work together. And the same would apply for "Watch all". I don't know why it is not working right now. (...) So to recognize what has been done on a map - it is possible to review the history. Which is basically a list of all changes which have been made. And if one user has made several changes they are aggregated to avoid a cluttering of the list [shows the history view]. We can see the details later. For example, Dennis created a feature [show a specific action in the history], edited geometries. Or edited properties would also be possible. Another action would be deletion of features and (...) reverting to older revisions which I am going to show now. So, you can click on a feature or select it from the history and you can review the changes which have been made or have been applied to a different - certain feature. Which can be either done by a slider on the left, or by the buttons [shows the "Show Changes" view and points to the slider and the buttons] here "older" or "newer" and you will directly see if a - the geometry has changes, which will also be highlighted [shows different versions of an existing feature] (...) Or even if the ...

I1: So changes of all users.

I: Yes. And the properties which have been changed. So at one time the category building/house has been set [points to the changed properties on the screen]. And now I can just browse through all the revisions to see how an object has been created. So, that was the spike I create earlier to show the synchronization [shows a the revision changes which have been made earlier in the demo]. And (...) it is also possible to revert to an older revision. So, if maybe some features have been (...) Maybe there were errors or mistakes and you could just say: Ok, that will be my new version [selects a revision and presses "Revert to revision"]. It will also apply to all other clients [shows that the feature has been updated on a different browser].

I: [clicks on "Show all workareas"] Oh, here it is working again. So you can see both work areas if I hit the button. Ok, and - the last feature I wanted to show today was, that it is possible to communicate within the - editor. So basically we have a chat functionality (...) and if I say for example "hi", it will be displayed to all other users [sends a message in one browser and shows the result in the other one]. What is different to existing chat functionalities or chat applications is, that we can refer to a specific feature. You can write a text [types a text inside the chat window] (...) and you can just click that button [points to and clicks the "Refer to feature" button] and click on the feature you want to refer to and hit send - and other persons can click on that icon and will - and the feature will be highlighted they pan to the feature which will allow to communicate about certain features.

I1: That's great!

I: For example in the user study, students used that to ask other students if this area they mapped really was a flooding. So they were unsure and they just asked the other students and a bit of communication came up. So (...) that were the basic features I wanted to show. Are there any other questions so far?

I1: Well so far I am thinking about the use-cases, and perhaps different requirements. And (...) one question would be: Am I working on a map with a large number of users, perhaps spread around the world? And editing different continents at the same time, or is it more focused on a certain region? Because I think this is relevant for the communication between people. Perhaps I have a focus of interest on a certain area where I want to work on and where I want to collaborate with others and I wouldn't want to interact with persons working on a separate continent. So, this would require perhaps a filter, somehow a spatial filter, a focus of interest for certain regions.

I: So, we have the possibility to chose different maps by name, which I showed at the beginning. Which could be used to (...) So we can here say we have a map name [shows the landing page of the application and enters a new map name]. So there is also the functionality to split different maps basically.

I1: So these are different projects you could say.

I: Yes. Different Projects. So if I enter for example a new map name, there are no features here [shows the difference between the two browsers and points to the empty user view] and we have no users. That's an easy way to just say: Ok, we have different projects and - they are stored in different databases and users wouldn't be in conflict with each other. And (...)

I1: So the assumption is that the focus of a map would be as specific that the user community really wants to interact and (...) it's a more focused context you would say.

I: I guess the application doesn't really make (...) doesn't really increase the value if persons are working on completely different areas. So if one person in editing in Europe and one person is editing in America, there is no synchronization value, because maybe you don't need the information the other one is providing. I guess the most efficient way to collaborate is on a really small area - so for example, in the use-case I used with the floodings (...) we had only a small area Dresden and therefore people really were forced to work together and to look over each others work. But there is the possibility to split up work and to provide basically separate rooms where persons (I1: focus of interest) are divided.

I1: So, (...) and the other question. I don't know if you have an answer to this. If working on a dynamic phenomenon. For example flood plane. (...) I'm still wondering what is needed to know - if the map is consistent in a certain situation. So, when someone is editing - perhaps is editing based on his observations. So he knows that a certain area is flooded right

now and so he will extent the flood plane in this area. But later on, (...) how can I know, that this information is valid for a certain point in time? (...) I just wondered. I don't have a - general answer what could be done. But perhaps you have thought about this.

I: I haven't thought about it until now. But I guess you would have to provide all the changed information. So if you have for example a background layer showing the floodings, it would be nice to have a layer before a certain time and after a certain time and - we could review the changes. And that would of course mean that - one person or a group of persons would have to manually look over all this data and have to analyze if there have been changes. But currently there is at least no automatic way to do it. So it would have to be done in a crowdsourced way. To just validate the work.

I1: Just an idea what could be helpful in this context (...) You already show the edits which have been made to a certain feature. And - it could be helpful to see the activities on a timeline and not only in a form of messages that something happened. For example in Github you see the contributions were over time. And if you see that it's more or less continuously edited. This could be helpful. And the other aspect is (...) one should think about. Where should a feature begin and end. If you have for example this flood plane around Dresden. Where does it end? This is again about the consistency and the integrity of the data.

I: I guess in crowdsourcing applications we always have the problem that we don't know if the data is valid. Or if the data is correct. And (...) Maybe it's a good idea to have the possibility to (...) maybe - up-vote or down-vote a feature. Maybe that you can - each user can apply a tag to a feature maybe saying - it's correct or it's not correct. So, if really a large amount of persons would work together and several persons are stating that a feature is correct, - you basically can assume that probably it's really correct.

I1: Perhaps you need some more (...) annotations. For example: a line feature just depicting the area were (...) you work on a feature for example. So just saying , with a line feature: up to this extent we edited the feature and not beyond. (I:ok) Or perhaps the possibility to edit - quality information. More meta-data. More saying, that - what I can approve that at this time, this - park or feature, or these features are consistent. I've done a quality check and I stand for it. For example. Just as an idea to think about the quality and integrity of data. And, if - there are possibilities to support this.

I: I guess that makes sense. Otherwise we just have large amount of data and no one knows what to do with it. So do you basically think that the feature history, (...) the older versions of a feature can be useful for those contexts? To really recognize what has happened?

I1: Yes, I think that's very important. To see what has happened to a feature and to see how it was edited, if it was refined somehow, or when did it pop up? So I know, - if this is plausible - so for a flood plane for example. I know that a certain part of a - river hasn't been edited than I am not able to

do any analysis on the data later on because I know that there are inconsistencies. And I get a feeling for the quality if have the possibility to look back into the history of the editing of a feature. That's very useful.

I: And, to the overall functionality of the user list. You mentioned earlier, that you would like to know when a person has edited a specific feature. Do you think the current features or the current possibilities are enough? So showing the workarea, watching a user and the highlights of the color?

I1: I think that's - useful - a feature I was thinking about was perhaps to reorder the list of users, or to (...) knowing if a user hasn't been inactive over time, than it gets down-rated in the list. So i know that these are the people which are currently active on the map. And this depends on the number of users. If you are always expecting two or three, than I think it's less important. If you expect that this could really be a crowd event with a larger number of users, than we have to think about how to present the list. Is it scrollable somehow and how you order it. As to make it useful with a large number of entries.

I: Maybe it would also make sense to only show users which are in the current viewport (I1: yes) - and only show all users - if you really click a button that says "show all users" and you know who is working besides me.

I1: Well this is something we mentioned earlier. It could be useful if (...) there are use-cases where you really have a large number of - editors and that all of them are interested in the same region. That - we well you have the possibility to set a spatial filter, which defines the spatial focus of your interest. So - and then you could say: Well, I just see the objects and I just see (...) the other users who are active in this field. Over the last (...) period of time.

I: Yes. I guess it's really important to know who is currently working in a area so that you can really collaborate. Do you think it makes sense to use this watch functionality for presentations maybe - or maybe to look at other users?

I1: I think it's (...) well I would use it - I think. Because if there is someone active I would just check what the person is doing in a certain situation. I don't think that it's essential. (...) So - if you think about - when reducing functionality to the max, this could be a candidate to be removed from my point of view.

I: So, an idea which came up was for example for users, which are not as experienced as maybe other users - to just watch other users work for a moment to get to know the workflow and - basically see how other persons would do their work, but (...) the watch all functionality could of course be very problematic if you have a lot of users. So that would be a bit of chaos if the map would change to often.

I1: But what would be interesting to see is, where are the activities on the map. To (...) perhaps you remember this - this video about history of edits of OpenStreetMap. (I: Yes) Where you see on the globe where things are happening. And you would have a timeline and just see that things have happened here or there. Or fields of activity somehow. Then you

would know, well there has something happened, or happening. There is the community working on something.

I: You already mentioned that, you think - the referring to feature tool could be helpful. Do you think there would be - more information needed to communicate about certain features within the map? Or do you think just referring to one feature is enough?

I1: Well you could (...) could think about - can be related to feature - this dialog and it could be related to any point in the map as well.

I: So more or less talking - not talking about a specific feature on the map but rather saying: Ok, let's look at Münster for example. Just a location name.

I1: Or you have a station and you have a question about - I don't know. Or a comment.

I: Requesting help at a certain location.

I1: Or an idea you want to share with others which is not directly related to a feature - but related to - a location. But I think for most of the dialogs will be about features. And this maybe sufficient already, but there may be other situations.

I: Yes. I guess just talking about simple locations could also be easily implemented and could help at the beginning where no features exist. As a more general question, do you think this kind of real-time synchronization can increase the efficiency when working together?

I1: Yes. I'm pretty sure that this is the case. (...) Particular in situations like this floodings situation (...) in disaster management. Where you have a point in time where a number of people come together and try to do something together. And they don't have the possibility - or they just don't want to agree on a certain process. But just doing things. And important that they are in the same context and they have a similar understanding of what has to be done. So the meanings in this map and - at that point - I don't know if you have enough support already for this, so that they are in the same context. As to be able to collaborate and - so it's just like a GoogleDoc you can start writing something. But as far as don't - you are not on the same context - it is not meaningful I think. Well there you don't have support - on this - within the GoogleDoc functionality - so it's questionable if this should be supported by the system itself, or if it's outside the system. But this is something you could think about for the support. For example you need information about the meaning of the categories. Is this accessible? Do you have documentation for this online? Or some do's and dont's which you can support the process there. But I think it's very helpful and perhaps the only way to really organize collaboration in those situations. So I think it's really valuable.

I: Do you think there should be more features to edit map content? For example, at the moment we have: drawing polygons, markers and lines. Just the very basic functionalities. Or do you think there should be more functionality known from for example really large GIS applications?

I1: Well I think you would have to check the use-cases again to see what's really needed there. For example with flood planes - would you need multipolygons for example. Right now, can you edit donuts? Is it possible?

I: No.

I1: So - well, this could be helpful if you have more possibilities there. But in general, I think it's a very good idea to start with these simple features and then extent if necessary. So to keep it simple as far as possible.

I: Maybe a use-case specific extensions.

I1: Yes. I think to analyze the use-case as to see what is really needed. This could help to evaluate this question. Another approach could be to look at standards - simple feature specifications. So, what is in it and (...) we are working on this because this complies to perhaps a lot of systems and they are able to work with this.

I: Do you think more complicated GIS functionalities like buffering or even doing analysis functionalities would make sense?

I1: In this context I would say: no. At least I could not imagine right now where it could be helpful. I think this Ethermap approach is really about editing and not about analysing. I think there are further contexts where you (...) further (...) editing functionalities are helpful. So to construct geometries for example. To measure things and to use steps as to measure something to be - to get a more accuracy in the data. But I think this may go beyond the main use-cases we have in mind.

I: Ok, I guess I am through with most of my questions. Maybe one last thing. Can you say something about what the usual workflow is when working together with multiple persons and you want to share geo-data or share maps? So maybe if you have a map or have data, what is your usual approach to provide this data to other persons.

I1: So you mean after editing, or in this editing process.

I: If you wouldn't have something like the Ethermap approach. So before the application came up. What is the normal way one would usually - share data?

I1: Usually you would not work in a synchronous way but in an asynchronous way and - say: Well, I'm working on this and then I hand over the result and then others build on this. And iterate. So, like you would do with word documents when you don't have this GoogleDocs. So I think this would be the way to do it. (...) I'm not sure about the concepts and technologies behind OSM were we have a large number of people working on the same dataset so I think there - this is a synchronous process as well (...) but I am not able with OSM to see what happens within the very moment. And so there might be conflicts and they have (...) processes, mechanisms to solve these conflicts. You can avoid these conflicts by synchronizing the editing process to the very moment. So I think this is a really big advantage in this context. Especially when many people are working on the same area, on the same objects.

I: Ok, do you have any other questions?

I1: No. Not anymore.

I: Ok, than I guess thanks a lot for your time.

[Skye-interview has started with only audio] I: Ok, now the recording has been started. I'll use screen-sharing - to start - to show you my prototype [starts the screen-sharing]. Ok. Can you see my screen?

I2: Yes.

I: I basically have two different browsers opened right now, and they both show the landing page of my application - and it's basically possible to choose a name for a map. So to say a project name and a user name. And I just typed in "Dennis" already and "Dennis2" for two names. And we are just going to create a new map. I'm calling it "test" for the moment. With those two browsers I'm basically trying to simulate different users within a map. What I'm able to to is - to draw features like it is known from other editors like polygons, lines and markers [shows the edit-tools via screen-sharing on the application]. So, we can do for example a simple marker here [creates a marker in one of the editors], and as you could see, hopefully, it directly appeared on the other map as well.

I2: Ok, great.

I: So, if you would be distributed among various places on earth, you could directly start working together. And of course, that's also possible for more complicated features like polygons. So I have selected a polygon here on the left [selects an already existing polygon and edits the geometry], and if I drag it around, it will directly be updated in other clients as well. So - that's basically one of the main functionalities. Really synchronizing the dataset between all clients. It's not only possible to change the geometry, but also to use categories, so properties for example - which are also known from OpenSteetMap - for example - a polygon can be a building, land-use or water. And we can just try to increase the level of detail here. So for example, a building can be a house and so on. And we can have different fields and properties. But I guess that's familiar from tools like OpenStreetMap. (I2: Yes) Ok, then another feature would be that we want to know what has happened on a map. I have a history, of all changes which have been applied on this map [opens the history view]. And you can basically see we have here - changes only by two persons, so the two map clients. There have already been features existing here. So we have - basically a lot of different edits here. And different edits from one person are aggregated to avoid a cluttering of this history. So for example, you can click "show details" [clicks show details on an aggregated history item] and you would get all (...) changes I made. (...) We can see, if someone edited a property, or the geometry but also if someone would have created a new feature, or deleted, or something else. Another part of my work was to display the actual history on a feature level. So we can select a feature and say: Ok, show changes [clicks on a feature and opens the feature history], which will basically be a version control for feature geometries. So we have here a slider on the left, which - if I drag it down, shows has

been created over time [drags the history slider of a feature up and down]. And therefore would be able to - review changes which have been made by several persons directly within the map context. And it would also be possible to revert the state of the polygon to an older revision - with just a button click here: "revert to this revision". [shows the button in the application]. And this would of course also apply to all other clients [clicks the button for an older revision and shows the changes in the other browser].(...) And - one last thing I just want to show within this demo is - a little bit of user awareness, I tried to create. So, we have a list of all active users [shows the user list] and as you can see here - in two different clients - in two different browsers we have the two different users which are currently logged in. This basically allows us to review other editors which try to collaborate with us - in this map. We can show the workarea of other persons which allows us to see where someone else is currently working on [clicks show workarea] . And, we can also try to communicate - so we have a basic chat functionality. What is different from known chat programs is, that I tried to enable communication about individual features. So we can do for example [types a sentence and references a feature within the chat]: "What do you think about:" and click this "refer to feature" button and just say: Ok, I want to talk about that feature. And other persons can directly relate to that feature or can see what is it about by clicking on it. (...) Are there any questions so far?

I2: No questions so far. Each time I think of a question, you show me what I was thinking about.

I: Ok, that's nice. So (...) I have one last feature I want to show you, and that's basically some sort of presentation tool. It's also possible to - basically watch another person which is basically done by toggling just a button here [shows the watch button in the user list and clicks it]. And if some person moves the map, the other person will directly been synchronized on the viewport level. And - I guess this could be helpful if a person would try to show another person something, or just for - displaying what another person is currently working on. (...). So that would be basically the prototype I wanted to show. And I would now start with a few questions of my own. (I2: Ok). But feel free - to ask anything if you like to. It's more or less supposed to be a discussion. Just to gather a few information about the overall concept (I2: Ok). You already mentioned, that you use tools like for example GoogleDocs. Can you maybe tell me a little bit about, what is the main purpose for you, when using such a tool?

I2: Collaboratively creating documents. So typically (...) like I just submitted a book chapter this morning that I was writing with someone else. So we - in real-time collaborated the outline - but then each person would work on their portion separately. So it allows us, you know, to be - quickly.

I: So basically, you use it for the first steps of the work. So you define the individual work packages, and after that each person is more or less working on the individual parts?

I2: In this case, yes. There is other times, where we do more with Hackpad. Where we are having a meeting in some other

medium. And then to collaboratively take notes for the meeting as well. So one person isn't doing all the work.

I: Ok. Than I guess you are already quite familiar with the overall concept of synchronously working together. So just as an overall idea, what do you think about the prototype you just saw? So, do you think this concept could be useful?

I2: Yes, definitely. Right now, a lot of the times if we try to do something similar, instead we would just use screen sharing and only one person would be able to control the map. So I think - For teaching there is certainly a huge benefit - on being able to edit in real-time. And also to better - working together. Right now, we have a tool we call our tasking manager, which just divides areas to work in into squares. (I: Yes, I know.). And the reason that is, is because since things aren't in real-time you have to - you know - make sure people don't collide with each other in a different way.

I: Yes. I was just in the task manager earlier this day. And I recognized this - basically this feature that an area is locked for all other users. So, I guess that's one of the main points for using a synchronous approach. That you don't have to lock a complete area where someone is working on, right?

I2: Right. And we still - even - and since it's a soft lock, we still run into issues, because - someone can still wander into someone elses area. But you don't know when there is a conflict in the editing, until both people have uploaded to OpenStreetMap.

I: Ok (...) so do you think, there is a different when working together collaboratively with geodata or with text?

I2: I don't think there should be a difference. I think there is just (...) since a lot more people use text than geo-data, more progress has been made. Like GoogleDocs and Hackpad. There has been - I know there have been companies that had collaborative tools for geo-data. But I actually have never played with them. They aren't as common as you might think they would be [laughs].

I: Yes, that's what I thought as I started with my master thesis [laughs]. And I was basically astonished that there isn't much more work done around this topic. Because I guess Google-Docs has been around since 2006 or so. So quite a few years (I2: Exactly). Ok. What do you think about the overall concept of this interactive feature version control? So, reviewing the changes directly within the map and - allowing persons to - revert to older versions of this feature.

I2: I think that's definitely important. Especially when you have new editors. Having an easy way to go back, and one: show the mistakes, and two: correct mistakes instead of redoing the work, you could just go back in time.

I: Yes. Ok. And do you think this overall history of the complete map is useful? Or do you have any knowledge if this kind of feature is used in OpenStreetMap by persons?

I2: There is a history feature in OpenStreetMap. People use it. The way the - it doesn't work as well as it should. Because, what it does is - it's supposed to be doing the bounding box of the area you screen is on, but it's based on the bounding boxes

of edits, rather than features. And it's not just ones included, but also ones that intersect. So you get a lot of garbage in the query. So I think by doing it by features - by overall features - in an area that's being worked on would make a lot of sense.

I: Ok. (...) And, (...) What do you think about this overall concept of allowing users to see basically who else is working on this map? So, the list of user and the tools for watching and showing the workareas?

I2: Yes. I think that's useful. And I think definitely being able to chat with them and than - and I thought chatting about a specific object was really cool as well. Because it is an easy way to point them at - at an object if you had specific questions about it.

I: Could you imagine using this kind of watch tool, for example for presentations? Like, remote presentations to other persons if you really try to show some geo-data?

I2: I think so. Certainly with the - I could imagine using it with a conference call, or a Skype call. (...) Typically I think if I would trying to do a similar thing now, I would probably take screenshots. So it wouldn't be interactive. So if there were questions, (...) it wouldn't be as flexible.

I: I know that in - for example the task manager of Open-StreetMap - there are a lot of functionalities like - connecting streets and - so more features on the editing tools. To really create a - valid dataset and a complete network for example of streets. I currently only have - creating markers, points and lines. Polygons, which can be edited. Do you think for such an application, it would make sense to include more complicated functionalities.

I2: It depends on what the overall goal is. I could imagine in the broader crisis mapping community this could be very useful. Meaning (...) it just - with the feature types that are available now. One feature I think would be useful, would be some sort of spreadsheet to view the attributes available for the features in an area. Because a lot of times people will try to - will be creating a dataset of something. So for example, maybe they are trying to map all the hospitals in an area. And so, you want to be there geographically, but then also potentially be able to search to text and also maybe to even edit directly in the text to fix things like, misspellings, or add additional information, which is available.

I: So this - spreadsheet would be about all features in the current map area? Or only about one individual feature?

I2: I think, - I would think maybe all in the map area, but I think what is difficult about that is, (...) they have a lot of different information about them. There isn't maybe a neat way - to view that very well. But maybe a type of feature. So if you want to look at all the buildings in an area you could do that in a spreadsheet. So maybe there would have to be a filter step, to get to - you know - a table that would be neat from a data perspective.

I: Ok. I haven't thought about that before. So - I don't know if you still see my browsers here. (I2: I do). Currently I only have the properties on a feature level. So for each individual

feature [clicks on a feature and shows the properties] here on the right. I guess, we lack an overview of all information which is currently available.

I2: Yes.

I: Do you think more complicated GIS functionalities would make sense within such a map? Like, doing really GIS analysis or buffering and stuff like that?

I2: I think the more simple analysis might be useful. In principle, I would mean buffering or maybe (...) sorts of items that are fairly common in a lot of web maps. I think it's certainly useful as it is know. But potentially with - if you were having a discussion or a meeting - having this additional tools could be useful.

I: Ok. How do you think it could be used for a tool for disaster management? So, I don't know - how often persons currently - for example in the task manager - are working directly at the same time. Do you think the use-cases would be different?

I2: Maybe not specifically related to OpenStreetMap. I could see - it be used for planning. Maybe for logistics for example. Where - let's say you have the features of (...) road blockages - or places you could land an aircraft. And be able to - discuss the possibilities. Might be one way of using it. Or if you had refugees or something like that, and needing to do planning. It could contribute - to a meeting. I would - . I don't have a lot of experience with those sorts of conversations, but I would - one person showing a Powerpoint presentation. So if you wanted to change things or look at different scenarios. I think it would be fairly awkward now, if you couldn't just say: What if we would do this, and then move a feature or something like that.

I: Yes, that's right. There is one feature I forgot to show earlier. To the topic of user awareness. Every time you edit a feature, so for example this marker [starts editing a marker on the map], there is a distinct color, which is assigned to an user, highlighting this changes for a few seconds. So, - if I drag around this marker, it is highlighted with a blue color. And if I would do the same on that side [edits the same marker on the other browser], there would be a green color, basically assigned to the user. Do you think it's important to know, who is currently working on in the map? So for example, it's also possible to show who else is working on that exact feature right now. On the bottom right of each browser currently [edits the same feature on both browsers and shows the list of current editors].

I2: I think that it's useful. (...) I imagine for example, when you are in Google Docs you see who is working where. And you see a lot of times, maybe someone misspelled a word and you are going to fix it for them, or something like that. But if you see that they already have the cursor there and they are doing it, then you don't. You know, you leave it be. So I could see, maybe in a similar scenario, where - someone you work with closely - you would be like: Oh, ok, they are going to go fix that. I don't need to go edit that feature. Or: ok, that is what they are working on right now. I'll go work over here.

I: Yes. Ok. So - I don't know if its different for geo-data. Ok, for a marker it is really simple because we only have one position, but for - for example - a line here on the left [shows a line in the browser window], there are - the area could be much larger where the actual feature has been edited. I guess it could be important if some person would work at the bottom of a feature, or at the south of a feature. And another person would be working on top. To know if persons are working on the same features, but on a different part of it. I imagine that it could be useful, because you actually don't see the viewport of another person anymore. And you are working on completely different areas.

I2: Right. I think that some of the questions - with user-testing and maybe giving tasks - that would encourage people to do that sort of editing would be a good way to determine if it is useful. (...) Because - I think it would require some testing.

I: Actually, I already performed an user study with about 40 people, 40 persons working at the same data-set. And - it was already quite interesting. Because, a few people thought it was really distracting that a lot of features changed at the same time. But at the same time - I guess the larger amount of persons were really fascinated by how fast the dataset could be produced together. And really how - it worked out to - without planning ahead how everyone should behave, it still worked somehow.

I2: Yes. I could see how- if there were a lot of edits going on in an area, - how maybe that would be distracting to someone. But if maybe depending on, what the view is of the overall editing area. If they zoomed in, so they are just looking at fewer objects - it would - I guess it also just on the type of person.

I: And the map extent is of course as you mentioned a very big aspect. Because if we would be working on different continents. I guess the overall idea of this editor wouldn't matter anymore. Because no one would really interact with each other. Ok. So - I'm more or less through with my questions. But I have one or two left. I wanted to know, if you know anything about current approaches for storing different versions of geo-data. So, not even in the context of databases, but how users do it, if they for example have geo-data on their hard drive. Do you know what current ways are to do that?

I2: Yes. It's pretty terrible in most case [laughs]. A lot of persons would just have Shapefile with version numbers on them. And there is not a good way to - you know - apply differentials to them.

I: So basically different files with just the date for example as a name, or stuff like that.

I2: Right. I mean, there are certainly on larger scale projects, people would use - versioning using a Geodatabase of some sort. But I think most people don't end up doing that. I haven't looked into it. There is the GeoGit project, which people are hoping to make it easier - to - look at different versions.

I: I already took a - look at the project. That seems quite interesting. What is your current approach, when you try to share maps or geo-data?

I2: Well, most of the data we have - since I work primarily with OpenStreetMap, it sort of just has the idea of - the most current available data on the map. So, we don't worry about versioning as much as many other people would.

I: Ok. So do you have any questions left? Because I guess from my side - I'm through with most of my questions.

I2: Ok.

I: Ok, then I would say: Thanks a lot. It was very helpful for me to get a few - information really using geo-data, or maps for disaster management for example.

Appendix B.2.3   Christian Elfers
[Video demonstrating the application has started showing two browser windows on the Ethermap landing page]

I: Wir sehen jetzt hier die Startseite der Applikation und wir simulieren jetzt direkt verschiedene Kandidaten, bzw. verschiedene Nutzer die in der Karte aktiv sind. Wir haben die Möglichkeit einen Namen für die Karte anzugeben und einen Benutzernamen. Das ist im Prinzip einfach eine Art Projektnamen. [Names are inserted in the video] Und wenn wir das Ganze starten, dann haben wir im Prinzip zwei verschiedene Karten die erst einmal das Gleiche zeigen sollen. - Die Grundlegende Idee ist ja wirklich die Synchronisation von den Geodaten, also dass wir hingehen können und - [Video shows the synchronization] irgend etwas zeichnen und Änderungen werden eigentlich direkt übertragen. Das sieht man jetzt hier: Sobald man irgend etwas zeichnet, soll das Ganze wirklich auf der anderen Seite direkt erscheinen. Man kann auch Features editieren und - dise sind die direkt auf der anderen Seite sichtbar. Was man direkt sieht ist, dass Änderungen direkt kurz aufleuchten. Heißt, andere Nutzer werden darauf hingewiesen, dass sich irgend etwas geändert hat. Also nicht einfach nur - wie man das vielleicht ja auch von Google Docs kennt, man sieht da ja auch immer den Cursor von anderen Personen der irgendwo aufblinkt. So dass man sieht, was sich gerade ändert. Man sieht auch jeweils genau, welche anderen Nutzer gerade an einem Dokument arbeiten [Video shows other editors in the contextual menu when in edit mode], damit man ggf. Konflikte direkt schon im Keim ersticken kann. Ok, genau. Der nächste Teil wäre der Überarbeitungsverlauf [Video shows History tab with existing actions]. Was ja auch immer bekannt ist, in solchen Tools in welchen man mit mehreren Personen gemeinsam zusammenarbeitet. Dass man wirklich sieht: was ist an der Karte passiert?, wer hat etwas bearbeitet? - Und das Ganze dann unterteilt in verschiedene Aktionen. Also man sieht z.B.: die Geometrie konnte bearbeitet werden, oder die Eigenschaften von einem Objekt. Oder ein neues Objekt wurde erstellt und so weiter. Das ist dann einmal die globale Übersicht von einer Karte.

P3: Kann man da dann auch zurück gehen? In der History?

I: Genau, dass ist direkt das nächste was jetzt kommt. [Video shows history of individual features] Das ist dann die Übersicht von einzelnen Features. Man kann dann auch wirklich hingehen und sagen: wie ist ein Feature entstanden?

I3: Achso cool, die einzelnen Arbeitsschritte.

I: Also wirklich eine Versionskontrolle. Man kann sich auch textuell anzeigen lassen was für Eigenschaften sind ggf. verändert worden etc. - Und unten gibt es dann auch direkt den Knopf: "Revert to this Revision". Also wirklich einen Schritt im Arbeitsprozess zurück gehen. Das wird dann natürlich auch direkt zwischen allen anderen synchronisiert. Das sieht man dann auch direkt in der Geschichte, bzw. in der History wieder [Video shows History after a feature has been reverted]. Genau, der nächste Teil ist dann user awareness. Ist, dass man wirklich merkt, man arbeitet nicht alleine an dem ganzen Projekt, sondern mit mehreren verschiedenen Personen. Deswegen gibt es erstmal eine Liste mit allen Benutzern [Video shows user tabs with each showing the other user]. Aktuell sieht natürlich ein Nutzer jeweils nur den anderen, da nur zwei Benutzer existieren. Jeder Nutzer hat eine Farbe, die ihm zugeordnet wurde. Diese wird auch automatisch generiert (...) was ermöglichen soll (...) wer arbeitet jetzt, also wenn dieses Highlighting erfolgt - von wem ist dieser Arbeitsschritt und so weiter. (I3: Achso, ok). (...) Das ging jetzt gerade ein bisschen zu flott hier [rewinds the video] zum sprechen für mich. Genau, es gibt auch die Möglichkeit anzuzeigen, wo jemand anderes gerade arbeitet [Video shows the "Show Workarea" functionality]. Das sieht man jetzt nur ganz leicht von der Farbe her. Man kann quasi den Kartenausschnitt einfach mal anzeigen lassen (I3: Ok) um zu sehen: wo arbeiten anderen Leute an der Karte? Der nächste Schritt wäre (...) also diese "watch" Funktionalität, habe ich es hier genannt, dass man einfach einem anderen Kartenausschnitt folgen kann [Video shows the "watch" functionality]. Ich glaube so etwas in der Richtung gibt es ja z.B. auch in map.apps (I3: Follow me). Ich weiß allerdings nicht genau, wo da die Unterschiede sind, bzw. wie das genau funktioniert.

I3: Auch mit WebSockets.

I: Genau. Der letzte Teil wäre dann noch Kommunikation mit anderen Nutzern. Erst einmal einen normalen Chat, sage ich jetzt mal. Der Unterschied ist jetzt, dass ich versucht habe auch über Inhalte zu kommunizieren [Video shows chat with feature referring]. Heißt man kann, Geometrien oder Objekte anklicken (I3: Ah, cool) und dann direkt anderen Nutzern auch erlauben (...) diese zu sehen.

[the video shows the closing credits showing the used technologies]

I3: Frameworks, oder was ist das?

I: Achso, ja genau. Das sind hier noch meine Tools, die ich verwendet habe. Im Prinzip node.js für die ganzen WebSockets und Hintergrund - oder für diese ganzen Serveranwendungen.

I3: Abspeichern von den Geschichten und diese Channels öffnen und so.

I: Genau. Und CouchDB ist einfach nur meine Datenbank, die gewählt wurde, weil sie diese ganze Versionierung direkt von Haus aus mitbringt.

I3: Ah cool. Ja, sieht gut aus!

I: Ich hätte dann einfach mal ein paar kleine Fragen vorbereitet. Aber wir können das auch gerne als normale kleine Diskussion machen, falls es auch noch andere Aussagen gibt, die du noch mit einbringen willst.

I3: Lass uns doch einfach beides machen.

I: Zuerst wollte ich mal wissen, so allgemein: Nutzt du, oder nutzt ihr hier eigentlich solche echtzeit Kollaborationstools? Ohne jetzt den Kontext von Karten direkt im Kopf zu haben. Also wie GoogleDocs oder so?

I3: Also ich weiß, dass es punktuell eingesetzt wird. Bedarfsorientiert. Aber bei mir speziell - eher nicht. Also wir haben, - bei den Tools die wir einsetzen, kommt es eher darauf an, dass man kollaboriert, und weniger, dass es auch wirklich in echtzeit ist. Also das sind dann schon wirklich Spezialfälle. Mehr so: Evernote, wo man Notizsharing macht, die dann aber ein echtes synchronisieren abbilden. Also die I3chlich keine real-time Verarbeitung an gleichen Dokumenten (...) also ich würde sagen, eher weniger.

I: Und, falls die ganzen Sachen genutzt werden (...) was ist normalerweise der Anwendungsfall?

I3: Anwendungsfall ist, dass man an einem Thema arbeitet, aber schlicht räumlich verteilt sitzt. Wir haben Telearbeiter. Leute die nicht jeden Tag hier sind - die aber trotzdem zusammen arbeiten müssen. Wir haben (...) Ja, das wäre tatsächlich etwas für real-time. Angebotserstellung, dass man Text miteinander schreibt, ohne dass man dann am Telefon sitzt. Manchmal muss man das ja miteinander schreiben. Das sind solche Anwendungsfälle, wo so etwas im Augenblick wenn dann benutzt wird.

I: Gut, dann direkt die nächste Frage (...) Nach der kurzen Demo jetzt, was ist so deine Meinung zu dem allgemeinen Konzept.

I3: Ich finde das gut. Ich finde das sehr gut. Liegt aber auch daran, dass wir so etwas auch machen. Dieses Thema der Echtzeit Kollaboration grundsätzlich (...) sehr wichtig wird. Im Augenblick ist man mit den Sharing Paradigmen tatsächlich auch nicht in der Echtzeit. Und es gibt viele Anwendungsfälle, die dadurch einfach nicht adäquat adressiert werden können. Aus dem Bereich - ganz populär bei uns, ist das - in dem Bereich early responder. Also Katastrophenschutz, Zivilschutz, (...) es passiert etwas, irgendwelche Unfälle. Da wo tatsächlich Leute in echtzeit - Planungsleitsätzen, Militär (...) miteinander kollaborieren müssen. Wo man tatsächlich wie früher in einer Lageplanung, wie man das so aus dem Fernsehen kennt, wo alle in einem Raum sitzen - und es wird irgendwie an einer Tafel miteinander gezeichnet, dass man das dann tatsächlich digital unterstützt.

I: Das war auch genau der Anwendungsfall, den ich für meine Masterarbeit jetzt gewählt hatte. Ich hatte eine kleine

Nutzerstudie gemacht, wo es darum ging, im Fall von einer Überflutung, überflutete Gebiete gemeinsam zu kartieren. Ich hatte dann z.B. 20 Leute die wirklich gleichzeitig das gesamte Gebiet kartiert hatten. Und man hat dann wirklich gesehen, wie extrem schnell man im Endeffekt wirklich ist. Und wie schnell auch viele verschiedene Leute an einem Projekt gearbeitet haben, ohne dass vorher eine große Abstimmung war und es hat direkt - implizit funktioniert, dass jeder daran gearbeitet hat.

I3: Das hat den Unterschied, es muss halt was sein, wo dieser Echtzeit Aspekt eine Relevanz hat. Das ist bei Katastropheneinsätzen der Fall. Aber bei anderen klassischen Multimedia und Social Networking Geschichten ist der echtzeit Aspekt auch eher - sekundär, sage ich jetzt mal.

I: Genau, wenn es nicht wirklich auf Sekunden oder Minuten ankommt, oder ich sage jetzt einmal Stunden. Das Zeitintervall ist ja relativ flexibel ....

I3: Andere Anwendungsfälle - das müsste man denke ich wohl einfach mal ausprobieren, ob das ankommt im Markt. Ob das ein Thema ist, oder nicht. Das kann ich gar nicht sagen, aber ich könnte mir vorstellen, dass so Tourismus Geschichten etwas sein könnten. Das man, keine Ahnung (...) man macht z.B. mit Freunden eine Motoradtour. Das man sich miteinander unterhält, welche Route man dann nimmt. Ich weiß nicht, ob ihr das einmal gemacht habt. Bei uns ist das dann wirklich so, dass man tatsächlich Vorschläge austauscht und dass das dann auch immer mal holprig ist, wenn man dann darüber diskutiert. Wenn man sich da einen Abend hinsetzt, den PC aufmacht - eine kleine Telefonkonferenz macht und einfach mal kuckt, dass man gemeinsam auf die Karte malt. Auch da wieder der Anwendungsfall, die Leute sind nicht an einem Ort. Kann ich mir vorstellen, dass das viel einfacher wäre.

I: Ja, auf jeden Fall

I3: Helpdesk, Paketverfolgung, du bist mit dem Ding unterwegs, hast ein Smartphone, kuckst auf die Karte. Hast das GPS an, siehst deine eigene Position, sollst das Paket abgeben. Das passiert bei uns immer wieder [mentions home adress], wo ist [mentions adress again]? Weil es nicht direkt an der Straße ist. Das man dann tatsächlich in der Zentrale anruft und sagt, ich finde [mentions adress again] und die Zentrale hat vielleicht weitere Informationen. Das kann dann - so eine Session teilen und man würde sehen: da vorne steht er, er muss nur einmal links herum. Irgendwie das Gartentor ist gar kein Gartentor, sondern keine Ahnung was, und dann bist du da. Solche Anwendungsfalle, so im Helpdesk Bereich. Und da gibts tatsächlich dramatisch viele Anwendungsfälle. Ausfüllen von Formularen. Mithilfe beim Ausfüllen von Formularen. Unterstützung bei der Beratung von Kunden. Ich habe jemanden, der mit drauf schaut. Dass was man dann wirklich heutzutage mit so remote Desktop sharing Geschichten usw. macht. Aber das ist dann ja doch immer sehr kompliziert und eine höhere Einstiegshürde hat. Weil du (...) solche Dinge ja immer installieren musst im Zweifelsfall. Bei dem Beispiel was ihr habt, mit dem technologischen Antritt, brauchst du nur einen Websocket fähigen Browser. Da kann man mal davon ausgehen, dass sich das

bald, dass bald Standard ist. Heute muss man vielleicht noch kucken. Aber ich denke mal mit Chrome und Firefox - ich glaube alle Großen können das.

I: Internet Explorer sollte es mittlerweile auch können. Nur zurück, halt die älteren Versionen. Da wird es dann eher kritisch.

I3: Aber da muss man nur im Netzwerk Websockets freischalten, aber dann kann ja jeder von jedem Endgerät darauf zugreifen - und dadurch fällt diese Technologiehürde natürlich und dadurch wird das aus meiner Sicht für alle interessant.

I: Gibt es irgendwelche von den Funktionalitäten, wo man jetzt sagen kann, die bräuchte man jetzt eher nicht? Oder welche, die dir besonders gut gefallen haben?

I3: Kommt auf den (...) was mir gut gefallen hat, war diese Nachverfolgung.

I: Also die Versionskontrolle?

I3: Gerade wenn viele Personen arbeiten, man also Konfliktfälle hat (...) Undo Funktion (...) ist denke ich bei Bearbeitung in Echtzeit - heißt dann ja in der Regel auch oft nicht besonders in Ruhe, sondern vielleicht auch in kritischen Situationen, wo auch öfters einmal etwas schief geht, aus der Natur der Sache. Das hat mir gut gefallen. Vor allem weil das so aussah, als wenn das eine generische Funktionalität ist, die man grundsätzlich nicht nur für die Geometrie Editierung, sondern auch für andere - Aktivitäten machen kannst.

I: Ja klar. Also ich meine, jetzt aktuell - ich weiß nicht ob man es am Anfang gesehen hat. Es ist nicht nur möglich die Geometrien etc. zu verändern, sondern auch Eigenschaften. Ich habe aktuell im Prinzip die gesamten Attribute, die man auch aus OpenStreetMap kennt übernommen. Ob jetzt ein Polygon, ob das jetzt ein Gebäude ist, etc. Und die ganzen Eigenschaften kann man natürlich auch nachverfolgen und wieder bearbeiten.

I3: Das halte ich für wichtig. Wie bei allen Kollaborationsplattformen auch unabhängig vom realtime Aspekt. Aber - das ist mir nochmal da auch hervorgehoben, dass das nicht verloren geht. Auch wenn man es in realtime und sofort macht.

I: Wie sieht es mit dem Chat aus? Generell auch mit dem diskutieren über einzelne Objekte in der Karte?

I3: Austausch halte ich für wichtig. (...) Normal, ich denke, dass (...) eine telefonische Kommunikation auch gut wäre. Aber das geht halt nicht immer. Und da hat man eine Möglichkeit tatsächlich auch auf so einer Ebene tatsächlich miteinander zu kommunizieren, während man Dinge tut. Halte ich für wichtig. Es gibt ja auch diese APIs - die neuen APIs, aus dem Chrome umfällt, mit denen man auch so Speech, solche Geschichten, übertragen kann. Ich könnte mir vorstellen, dass tatsächlich das Chatting in anderen Bereichen auch oft nur ein erster Schritt ist, und man dann dahin kommt, dass man so Anwendungen auch automatisch wie diese Teamplay Geschichten, bei denen du Shooter - mit da einbinden kann.

I: Man ist halt über Sprache direkt doch meistens effektiver und schneller unterwegs.

I3: Eben.

I: Es gibt diese Funktionalität, bei der man anderen Nutzern folgen kann. Was ihr ja auch habt, mit dem "Follow me". Kann man sich da vorstellen, dass das auch wirklich als online Präsentationstool verwendet werden kann? Dass man - wird das vielleicht gemacht?

I3: Nein [laughs]. Das wird noch nicht gemacht. Es finden alle interessant (...) ja ist die Frage. Es gibt einen Kunden der das macht. Das ist Einsatzleitplanung, kann ich keine Details zu geben. Das ist confidential. Aber es gibt einen Kunden, da wird das gemacht. Da geht es auch noch viel weiter, als tatsächlich nur das (...) realtime sharing. Da gibt es auch Aspekte, dass Situationen zusammengefasst, aggregiert werden, on-the-fly. Aber, ansonsten haben wir das verschiedentlich vorgeschlagen, ist aber tatsächlich noch so (...) dass es ist noch keine - wie nennt man das - da gibt es ja das Kano'sche Dreieck der Funktion. Da ist es nicht in dem Erwartungsfeld, sondern es ist eher in dem Excitement - Feld. Es begeistert Leute und vermittelt darüber auch - eine Gewisse Eigenschaften für das Tool. Aber es ist nicht in den Basiserwartungen. Das wird da aber hinkommen. Das ist wie bei allen Gegebenheiten. Aus jedem Excitement Feature wird irgendwann, früher oder später ein Expectation Feature. Das könnte ich mir auch so vorstellen.

I: Was mich noch interessieren würde ist, ob man sich vorstellen kann, dass vielleicht auch komplexere GIS Funktionalitäten in so einer kollaborativen Anwendung Sinn machen. Ich meine, Standardfunktionalitäten in GIS sind ja: buffering - Analysen zu fahren, oder Schnittpunkt Berechnung usw.

I3: Ich weiß nicht ob das für realtime wirklich (...) ich kann mir schon vorstellen, dass es solche Situationen gibt. Aber ich könnte mir vorstellen, dass Analyseprozesse, die sich über mehrere Köpfe hinwegziehen in der Regel sequentiell sind. Also das man die Dinge aufeinander aufbaut. Zwischenergebnisse sind ja meistens Workflow orientiert. Also klar definiert. Mit der entsprechen Berechtigung, Übergabepunkten und auch fachliche Zuständigkeiten. Der Vorteil von der real-time Kollaboration ist ja, dass man die Dinge aus dem serialisierten Prozess heraus nimmt und sie parallelisiert. Das heißt, wenn dann kann ich mir vorstellen, dass es für solche interessant ist, wo das geht. Ich kenne aber keine. Also wenn es welche gibt, dann wäre das dafür sicherlich interessant. Bei den anderen Geschichten - könnte ich mir vorstellen, dass es zu mindestens für mittelfristig nicht so relevant ist.

I: Ja. Aktuell sind ja quasi nur die Tools enthalten für ganz simple Geometrien. Heißt, Punkte, Linienzüge und Polygone. Da könnte man sich natürlich überlegen, in wieweit es Sinn macht, das Ganze komplexer werden zu lassen. Oder ob es eher Sinn macht, das Ganze auch wirklich für Laien nutzbar zu machen - und möglichst simpel zu halten, ohne jetzt die Funktionalität zu stark zu vergrößern.

I3: Ich denke, was hier notwendig, - was hier angebracht wäre - oder was hier der nächste Schritt sein könnte ist, dass man sich tatsächlich praktische Anwendungen ankuckt. Eine Problemstellung an der man das braucht. Und dann diese Funktionalität als Grundlage zu nehmen und in diesen Anwendungsfall zu integrieren. Ein bisschen von dem technologischen Fokus, was alles geht - hin zu dem Fokus: was brachen wir denn überhaupt, um eine Problemstellung zu adressieren. Ich denke, da hat man dann noch (...) da weiß man dann direkt was man braucht. Ansonsten ist das schwer zu beantworten. Ob man etwas braucht, oder nicht hängt eigentlich immer von der Aufgabenstellung ab.

I: Ja klar - Genau, ich hätte jetzt noch ein paar allgemeine Fragen zu Arbeitsprozessen, die vielleicht - relevant sein könnten. Und zwar: erst einmal, wie - was ist normalerweise der Ansatz, hier zum Beispiel in der Firma oder bei Kunden um verschiedenen Versionen von Geodaten zu speichern? Wird das irgendwie sinnvoll durch Versionierung mittlerweile schon erledigt, oder ist das noch oft mit z.B. Shapefiles mit verschiedenen Versionsnummern?

I3: Nein. Das wird in der Regel durch Versionierung in der Geodatenhaltung im Augenblick abgebildet. Da wo es erforderlich ist als Versionierung. Wir sehen aber auch immer häufiger den Trend, dass man tatsächlich mit redaktionellen Ständen arbeitet, die man einmal herstellt und daran arbeitet man dann an dem Stand. Und irgendwann hat man dann einen neuen Stand. Also das man auf verschiedene Versionen parallel zugreifen muss, dass das zumindest auch - zumindest was meine Sichtweise angeht, doch auch eher harte Spezialfälle.

I: Und, allgemein im Prozess, wenn es darum geht - Geodaten anderen Nutzern zu teilen? Wenn es darum geht, Daten an andere weiterzugeben? Was ist da aktuell der normale Arbeitsfluss?

I3: Wenn man Geodaten an andere weitergibt?

I: Ich meine, gibt man dann einfach eine Shapefile weiter?

I3: Nein, in der Regel - also bei uns ist es in der Regel Servicebasiert. Das man so etwas aufsetzt und sagt: hier ist der Endpunkt, da kann man sich etwas herunterladen. Oder, dass man tatsächlich die Daten weitergibt. Ich meine, man muss auch da wieder das Anwendungsszenario unterscheiden. Wenn es darum geht, Daten weiterzugeben, damit diejenige Stelle, die die Daten annimmt, damit irgendetwas anderes aufbaut - permanenteres Interesse daran hat, sage ich jetzt mal. Dann wird man das per Datenübergabe machen. Einfach, damit man autark ist als Annahmestelle. Wenn es darum geht, dass man wirklich in real-time Daten shared. Für kurzfristige Geschichten. Eine gemeinsame Visualisierung, Nutzung in einer Analysefunktion oder sonst wie, dann ist sicherlich Webservice basiert auch eine gute Sache. So einfach wie möglich immer.

I: Genau. Ja, dann bin ich im Prinzip auch mit meinen Fragen durch. Ich hatte ja erwähnt, dass der Fokus auf user awareness, also das man weiß, was andere Nutzer gerade tun, für mich ja auch relativ wichtig war. Also das man z.B. diese Highlighting hat von anderen Nutzern, die Liste von Nutzern, dass man sich anschauen kann: wo sind andere Leute gerade?

I3: Absolut, ja.

I: Wie weit das als wichtig erachtet werden könnte?

I3: Sehr wichtig glaube ich. Also - es ist ja wichtig für Menschen, dass man nicht alleine ist. Ein Grundcharakterzug, würde ich sagen. Einfach zu sehen, wieviele Leute arbeiten noch gerade da dran. Oder kucken sich noch irgendwas an. Ist ja auch was, was einfach bei einem assoziiert: das ist irgendwie wichtig, oder das hat Relavanz oder so. Das sieht man ja auch in ganz anderen Bereichen. Wie viele Leute schauen sich gerade diesen Artikel an. Das schreibt man ja nicht ohne Grund rein. Sondern tatsächlich auch hervorzuheben, dass das Ding auch Relevanz hat. Wenn man halt alleine ist, dann sagt man nicht: Es schaut sich gerade keiner an, sondern man sagt dann einfach gar nichts dazu [laughs]. Also das halte ich schon für sehr wichtig.

I: Gut. Dann sage ich auf jeden Fall einmal Dankeschön. Oder gibt es noch irgendwelche Fragen dazu?

I3: Nein nein. Mir gefällt das gut.

Appendix C. FOCUS GROUP - DISCUSSION

I: Has anyone of you has directly any comments? - Or should I start with a few questions of my own?

P1: I guess I don't have many thoughts but - I realized somewhere that it would be nice that if you click on a geometry - that - to see who edited the geometry last. I didn't find a way to figure out who edited the object.

I: Yes - ok - currently it's only possible to see who is at the same moment editing. - There is a little box at the bottom - but yes, that's right.

P7: And the categories - for the land.

I: Yes - categories basically. P8 already told me, that it is - not possible at the moment to explicitly say - there is a street which is free - so you can only map blocked areas, which is of course a problem.

P8: I mean it was the task to map blocked ares. But from experience I know that people don't care about tasks in disaster management - they basically map everything they get at hand. And sometimes even if ask to map blocked roads - something that is not mapped as a blocked road does not neccessarily tell you that it's free. So if you want to emphasize that a road is free - it would be nice to have that category or another category - maybe create that one on your own or something.

I1: I have two comments. - The first comment is: It would be nice if there is an option like to switch of showing others work. - Because sometimes it is distracting.

I: What exactly made you distracted?

P1: Because I mean - If I tried working on something and someone also mapping the area - It confused me, so like - should I continue to work or should I stop.

I: Ok, but - Do you also think the many colors and highlighting features were - distracting - or only that the geometry was changing?

P1: The geometry as well as the color.

I: That's a good point

P1: And my second comment is - It would be nice - When we are editing a feature or we add a feature - To just give a short description of what we where doing.

I: So basically like commit messages in GIT? So you can say - ok, I edited the geometry or -

P1: Yes. Because we don't know if someone changed a feature because of an error or mistake.

P3: It would also be nice to have a - some kind of collective agreement on - how to edit features. Somehow that we know - for example - that in a a situation - that you see that people start editing next to you or the same thing - what is your behaviour supposed to be in this case? Should you finish you what you were doing or are you supposed to stop editing. I was thinking that maybe the other person would be better - or maybe also I was thinking - that he has some kind of speciality. You could distribute the work across areas somehow - or assign tasks to the users based on the categories as for example blocked buildings - and you are responsible for looking for blocked areas etc.

I: So you would basically set some kind of moderator of some kind? Like some person responsible for just telling people where to map best.

P3: Not per se, you would just have to say at the beginning, I am responsible for that smaller area. So you know, this is my area of responsibility and I'm going to work on that. And that way (...) I think sometimes you can get distracted because you see so many different things and you want to start edit here or there. But I think the first thing is more important so somehow - a collective agreement on how you are supposed to behave in situations were several people are doing something next to each other.

P4: I agree with P3. And also I would like to add some point, there should be one person who controls a region.

I: Ok - and what excatly would this person be supposed to do?

P4: I mean, he can check for the validity of the commits. And he could also has the option to delete someones work.

I: But wouldn't it be better to distribute that workload to all other persons? So maybe every edited feature can be validated. So - for example, I can validate your work and you can validate my work and not just one person validating everything?

P4: But we are talking about the aspect of accountable data. - I mean, someone should be accountable, right?

P12: Perhabs it helps to have this - informal training? Where the special taskfore showing that you have different roles. One is doing the rough geometry, so that when you log in you say I am doing the rough geometry and I don't care if it's accurate. And the next person is doing details and the next one is doing validation. So that we limit the functionality based on the roles - for which you sign up or switch between while you are in there. But each role comes with a description

(...) that could somehow help with an collective agreement by saying I'm responsible for that business.

P5: What I found intresting is that - at the beginning - i would like to - besides from having the tutorial on how to use the buttons and so on, I think it would be great to have a way to see which users are more experienced who are currently in the map. So you can take them as an example. Because before I started mapping something, I first looked what the other persons were acutally doing and how accurate they mapped stuff. (...) how accurate the mapping should be.

I: So I guess it would be easier if a subset of features or geometries would already be existing.

P5: Yes that would be one thing - and the other thing would be great to know people who are working right now, how experienced they are in terms of mapping. How much they had already contributed. Maybe they are professional mappers and you could, you know, at first observe what they do and how they do this and then copy the way of doing the mapping. That would be helpful for people who just started.

: At the beginning - one should see an example of some work. Maybe even fake a user who's fame is something like superpro and everyone can look: that is the level of accuracy for which I should aim at least. And if you see rough polygons you know if it's acceptable.

I: This would of course include some sort of user account. At the moment you can just choose a log in - choose a random name and start editing. And if you want to know how experienced a person is, you would have to create a user account. That is probably - I think to discuss also. Because some people may don't want to create an user account.

P1: If we use the same name, does it relate for all edits we commited?

I: But I couldn't just choose the same name. And could maybe try to gain for example your achievements also.

P8: So the same name results in the same persons?

I: No, (...) there is an internal id.

P8: My feedback or comment would be, that appart form the commit message you should have a general description for everything you describe - or everything you tag. I don't know, you said that the commit message - that you just have a general description of what is seen. (...) Maybe a name or something - to have a - set of properties which you can fill out - Predefined - or precomposed properties.

I: Do you think there are features missing in the map - which - in regard to the editing tools? Do you think editing points, lines and ares are enough? Or would you say - ok - we would need for example texts directly on the map or other features?

P10: I think when you click on the category - on the icon on the map - maybe it would be better if we - would see the others made this icon - to be easier to know which others edited.

P4: Or maybe a "last edited by" over each polygon.

P3: There could be something like a question mark. You see that is something has been going on - maybe something that you don't understand but maybe someone else does. So, that way you wait but somebody else might comment or resolve the issue.

I: So communicating about the changes is a very important aspect.

P12: Requesting help

P11: Yes for specific areas.

P12: So someone could just jump in and edit everything on the fly.

P9: There would a certain - a specific kind of marker acutally, that's a question mark.

I: As far as I noticed, noone of you used the chat functionality. So - was the timeframe just to short? Or -?

P8: The situation is quite special I guess in that moment. There is nothing that has been tagged and everybody probably just took an area and started tagging somewhere - like cracy. So we didn't progress that much that you can say - that you would for example discuss how you map something.

P9: Maybe the task was to simple. (...) Maybe you have to show us how, this is how the complete map should look like and you have 5 minutes to do it. And than we would have think about how do do it.

P8: But it was the task to not communicate. Not with each other.

I: Not communicate in Person.

P9: No, we woud have to coordinate within the chat. So I would just say "I start in the north" and then I just do it. And someone else might say "that doesn't make sense because I'm already doing that".

I: I guess in ten minutes you don't rely have to rely on communication because - as the area is large enough for everyone to just start mapping and nobody really interfers.

P10: I think it would be good to know a particular objectives. So in this case to map blocked areas - and flooded areas. So in that case we have categories but it would be better to say the tasks and say the objects at the beginning ands this is this, and these are some example objects. So this is a blocked area and this is a flooded area. So that the users know exactly what they should look for. Otherwise the persons just creating - capturing all the objects like the roads or lakes. (...) I don't know if I missed something.

I: Do you think there are other use cased which are more suitable than disaster management? General use-cases you could this kind of application for.

P10: You mean use-cases?

I: Yes. General aspects - or general use-cases you could apply - problems you could solve with this kind of application.

P10: We used this editor for - to collaboratively change something. At the beginning, the people who are editing should know what they should do and how the final outcome should look like. That should be clear at the beginning.

P12: And it would better for the collaborataion - that you create communication. - For example, communication between the users. To know, how they communicate with each other.

I: Do you think maybe a to-do list would increase - the collaboration?

P10: Yes

I: So one person could just type in to-do list items and other people could say - "I will do that item" and you would at some point have a large list of items at some point where people could actively choose from those items. So users would have a specific task where they can perform.

P3: Another way would be to make the area smaller and request that the mapping - or the annottion should be very precise. Therefore people would have to edit each others work and a simple task could be done faster. Now it was more like everybody mapped somehow. But if you have a really tiny - area - I think as we already discussed an example of how the map should look like - and then it would help to force people to cooperate.

I: Do you have any use-cases besides disaster management in mind - which could be useful?

P2: We had experimented with a similar kind of mapping but not with the version control - for a crime incident map. So people can record a crime on a map - form the field.

I: Do you think it would be possible to apply really complex GIS tasks on such a map? Like performing analysis of specific areas? I don't know for - I'm lacking an example right now. But - what's a common GIS analysis?

P1: Get the shortest path.

P9: So people would start mapping from both ends and would come up with a route?

P8: I think mapping is the most crucial task. You could do for example a shortest-past algorithm or other calculations automatically or semi-automatically.

P9: You would basically map the roud network. And then take the data for that analysis.

P1: It could also be used for conferencing, so that you can show things on a map and - see it graphically. We all know Skype and used screen-ssharing to show other persons something. If you have a task that has been mapped, you could just show without screen sharing and discuss it with interaction.

P12: It is like if we would like to decide now where we should go - in the evening. We could come up with different routes for one purpose. And the others could jump in and map that.

P9: So you just say - we start here and we end there, that's the line.

P12: So building consensus.

P3: And you could also say, "ok that buiding is nice, we should go there". So you could not only ask for routes but also for locations. For example "we should cross this place, there is a nice pub".

I: That's a nice scenario. Finding bars.

P9: But this consensus actally - I mean - We can always have troubles. - Maybe the system could support the consensus creation. (...) What most things are we came up with are workflows for particular applications that are - are just usages of the technologies. (...) What I'm thinking about most is - what workflows around that, for example asking for help. It's just some kind of democracy. Using the system as a toolbox is gonna be appealing for many use cases.

P8: I would have a general feedback on the features. - I find it sometimes quite hartd to decide where a flooded area ends and where dry areas start. The rectangle or the polygon was - had a very sharp end. So here is a flood and there is no flood. So do I move the - polygon until here, or until there? So, I know that is technological quite hard to conceputalize. But it would be nice to have an open polygon where you can define, ok - it goes until somewhere there.

P12: But that's not possible. A polygon can't be open.

P8: Yes, technically not. But conceptually.

P12: That isn't possible.

P8: Yes, but the border could be.

I: Well you could just draw a second polygon and say ok, - "here is less amount of water existing" or "the flooding is more intense, here". - So, more categories maybe.

P8: Yes, also partially flooded or (...) sightly flooded or whatever. (...)

P12: This is use-case specific.

P8: This is definitely use-case specific. - But I know from disaster management, that you have other use-cases as well for example, responsibilities, so you take the east part and the west part and the north part of the incident and you say, - just it's a triangle that basically is two lines - and you have a corridor that - could theoretically go to infinity (...) but it has to end somewhere. But it doesn't matter at all. So if you map that from a technical perspective - this triangle has to end at some point. It's technically not possible but - conceptually.

I: Ok (...) It's half past twelve. - Do you have any last comments or should we end the discussion? (...) I don't know if you are hungry.

P9: Make it open source.

I: I am planning on doing that.

P6: Is the editor iD based?

I: No, it's just - the map library is leaflet - and that's basically the same framework iD uses. (...) But they have built around their own framework. (...) Because it's just more easy to (...) because you don't have to rely on all these other funcitonalities and make sure you don't break them in the process.

P10: Open source it. [laughter]

I: Yes, it's already on GitHub, but it's a private repository. So - maybe if my thesis is completed I'll open source it.

P9: Nice work.

Appendix D. CORRELATION MATRIX

Appendix D.1   Question Keys for the Matrix

Table 3: Question - Key list. Required to interpret table 4

Question	Key in Correlation Matrix
Mental Demand	1
Performance	2
Effort	3
Frustration	4
Haben Sie bereits Editoren mit echtzeit Synchronisierung verwendet?	5
Wie würden Sie ihre Erfahrungen mit Geographischen Informationssystemen einschätzen?	6
Ich konnte die Anwesenheit von anderern Nutzern sehr gut wahrnehmen.	7
Aktionen anderer Nutzer haben mich bei meiner Arbeit nicht gestört.	8
Ich konnte Änderungen von anderen Nutzern gut erkennen.	9
Ich habe aufgehört ein Geoobjekt zu bearbeiten, weil jemand anderes auch gerade das Objekt bearbeitete.	10
Das Highlighting von Geoobjekten bei Änderungen von anderen Nutzern hat mich bei meiner Arbeit gestört	11
Ich war mit der Geschwindigkeit zufrieden, in welcher der Editor meine Änderungen übernommen hat	12
In gemeinsam bearbeiteten Karten ist es hilfreich einen Überarbeitungsverlauf zu sehen	13
Die verschiedenen highlight Farben haben mir geholfen zu erkennen welcher Nutzer ein Geoobjekt bearbeitet hat	14
Das Anzeigen des Kartenausschnitts von anderen Nutzern hat mir geholfen die Anwesenheit von anderen Teilnehmern besser wahrzunehmen.	15
Ich glaube, dass durch die echtzeit Synchronisierung die Aufgabe effizienter gelöst werden konnte	16

Appendix D.2   Correlation Matrix

Table 4: Matrix showing the correlation coefficients. Used to check if their are statistical relationships between different questionnaire results. Row and column keys correspond to the keys in table 3

Key	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1,00	0,37	0,60	0,46	0,34	0,09	-0,02	0,14	-0,01	-0,10	-0,23	-0,15	-0,24	-0,10	0,01	-0,23
2	0,37	1,00	0,27	0,56	0,09	-0,01	0,07	0,07	0,15	-0,05	-0,34	-0,07	-0,00	0,10	0,33	0,19
3	0,60	0,27	1,00	0,17	0,15	0,13	-0,05	0,04	-0,18	0,02	0,01	-0,07	0,04	0,04	0,02	-0,16
4	0,46	0,56	0,17	1,00	0,26	0,31	0,13	0,17	-0,20	-0,06	-0,19	-0,27	-0,04	-0,01	0,16	0,22
5	0,34	0,09	0,15	0,26	1,00	0,30	0,32	-0,02	-0,19	-0,00	-0,12	-0,17	-0,04	0,21	-0,04	-0,16
6	0,09	-0,01	0,13	0,31	0,30	1,00	0,07	0,02	0,02	0,06	0,01	-0,12	-0,10	-0,10	-0,31	0,21
7	-0,02	0,07	-0,05	0,13	0,32	0,07	1,00	0,05	-0,26	0,00	-0,06	0,40	0,37	0,38	0,19	-0,03
8	0,14	0,07	0,04	0,17	-0,02	0,02	0,05	1,00	0,07	0,10	-0,29	0,10	-0,27	0,03	0,17	0,03
9	-0,01	0,15	-0,18	-0,20	-0,19	0,02	-0,26	0,07	1,00	0,16	0,17	0,07	0,01	0,07	-0,01	-0,06
10	-0,10	-0,05	0,02	-0,06	-0,00	0,06	0,00	0,10	0,16	1,00	0,28	-0,08	-0,07	0,08	0,07	0,05
11	-0,23	-0,34	0,01	-0,19	-0,12	0,01	-0,06	-0,29	0,17	0,28	1,00	0,07	0,07	0,07	0,20	0,05
12	-0,15	-0,07	-0,07	-0,27	-0,17	-0,12	0,40	0,10	0,07	-0,08	0,07	1,00	0,23	0,05	0,19	-0,01
13	-0,24	-0,00	0,04	-0,04	-0,04	-0,10	0,37	-0,27	0,01	-0,07	0,07	0,23	1,00	0,08	0,25	0,22
14	-0,10	0,10	0,04	-0,01	0,21	-0,10	0,38	0,03	0,07	0,08	0,07	0,05	0,08	1,00	0,46	0,32
15	0,01	0,33	0,02	0,16	-0,04	-0,31	0,19	0,17	-0,01	0,07	0,20	0,19	0,25	0,46	1,00	0,23
16	-0,23	0,19	-0,16	0,22	-0,16	0,21	-0,03	0,03	-0,06	0,05	0,05	-0,01	0,22	0,32	0,23	1,00

Allgemeine Informationen

Vielen Dank für das Teilnehmen an der Umfrage. Der Fragebogen ist anonym. Es werden keine personenbezogenen Daten gespeichert.

* Required

1. **Teilnehmer Nummer** *

   ………

2. **Alter** *

   ………

3. **Geschlecht** *
   Mark only one oval.

   ◯ Männlich

   ◯ Weiblich

   ◯ Möchte ich nicht sagen

4. **Wie würden Sie ihre Erfahrungen mit Geographischen Informationssystemen einschätzen?** *
   Mark only one oval.

	1	2	3	4	5	6	7	
Experte	◯	◯	◯	◯	◯	◯	◯	Keine bisherigen Erfahrungen

5. **Haben Sie bereits Editoren mit echtzeit Synchronisierung verwendet?**
   Beispiele: Google Docs, Etherpad, ...
   Mark only one oval.

   ◯ Ja

   ◯ Nein

   ◯ Keine Ahnung

6. **Falls ja, welche Editoren mit echtzeit Synchronisierung haben Sie verwendet?**
   Nur ausfüllen, falls die vorherige Frage mit "Ja" beantwortet wurde.

   ………

   ………

   ………

   ………

   ………

Funktionalität des Editors

7. **Ich konnte die Anwesenheit von anderern Nutzern sehr gut wahrnehmen.** *
   Mark only one oval.

	1	2	3	4	5	6	7	
Starke Ablehnung	◯	◯	◯	◯	◯	◯	◯	Starke Zustimmung

8. **Aktionen anderer Nutzer haben mich bei meiner Arbeit nicht gestört.** *
   Mark only one oval.

	1	2	3	4	5	6	7	
Starke Zustimmung	◯	◯	◯	◯	◯	◯	◯	Starke Ablehnung

9. **Ich konnte Änderungen von anderen Nutzern gut erkennen.** *
   Mark only one oval.

	1	2	3	4	5	6	7	
Starke Zustimmung	◯	◯	◯	◯	◯	◯	◯	Starke Ablehnung

10. **Wodurch konnten Sie Änderungen von anderen Nutzern am besten erkennen?** *

    ....
    ....
    ....
    ....
    ....

11. **Sind während der Nutzung des Editors Fehler aufgetreten?** *
    Mark only one oval.

    ◯ Ja

    ◯ Nein

    ◯ Keine Ahnung

12. **Wann immer Fehler aufgetreten sind, konnte ich danach schnell wieder weiterarbeiten.**
    Nur ausfüllen, falls die vorherige Frage mit "Ja" beantwortet wurde.
    Mark only one oval.

	1	2	3	4	5	6	7	
Starke Zustimmung	◯	◯	◯	◯	◯	◯	◯	Starke Ablehnung

13. **Ich habe die Versionskontrolle verwendet um Änderungen an der Karte rückgängig zu machen.** *

"Revert to revision" Button in der "Show Changes" Ansicht eines Geoobjektes.

Mark only one oval.

( ) Ja

( ) Nein

( ) Keine Ahnung

14. **Die "Show Changes" (Versionskontrolle) Ansicht hat mir geholfen, die Entwicklung eines Geoobjektes zu verstehen.**

Nicht beantworten, falls nicht verwendet!

Mark only one oval.

	1	2	3	4	5	6	7	
Starke Ablehnung	( )	( )	( )	( )	( )	( )	( )	Starke Zustimmung

15. **Ich habe aufgehört ein Geoobjekt zu bearbeiten, weil jemand anderes auch gerade das Objekt bearbeitete.** *

Mark only one oval.

( ) Ja

( ) Nein

( ) Keine Ahnung

16. **Haben Sie den Chat verwendet?** *

Mark only one oval.

( ) Ja

( ) Nein

( ) Keine Ahnung

17. **Warum haben Sie den Chat (nicht) verwendet?**

....

....

....

....

....

18. **Haben Sie das "Refer to feature" Tool innerhalb des Chats verwendet?** *

Mark only one oval.

( ) Ja

( ) Nein

( ) Keine Ahnung

19. **Warum haben Sie das "Refer to feature" Tool (nicht) verwendet?**

....

....

....

....

....

20. **Das "Refer to feature" Tool hat mir geholfen über Objekte in der Karte zu kommunizieren.**
Nicht beantworten, falls das Tool nicht verwendet wurde.
Mark only one oval.

	1	2	3	4	5	6	7	
Starke Ablehnung	◯	◯	◯	◯	◯	◯	◯	Starke Zustimmung

21. **Haben Sie das "watch" Tool verwendet? ***
Das "watch" Tool wird verwendet und aktuellen Kartenausschnitt mit einem anderen Nutzer zu synchronisieren.
Mark only one oval.

◯ Ja

◯ Nein

◯ Keine Ahnung

22. **Warum haben Sie das "watch" Tool (nicht) verwendet?**

....

....

....

....

....

23. **Haben Sie das "Show Workarea" Tool verwendet? ***
Button in der Nutzerliste zum Anzeigen des aktuellen Kartenausschnittes von anderen Nutzern.
Mark only one oval.

◯ Ja

◯ Nein

◯ Keine Ahnung

24. **Warum haben Sie das "Show Workarea" Tool (nicht) verwendet?**

....

....

....

....

....

25. **Das Highlighting von Geoobjekten bei Änderungen von anderen Nutzern hat mich bei meiner Arbeit gestört** *

Mark only one oval.

	1	2	3	4	5	6	7	
Starke Zustimmung	◯	◯	◯	◯	◯	◯	◯	Starke Ablehnung

26. **Ich war mit der Geschwindigkeit zufrieden, in welcher der Editor meine Änderungen übernommen hat** *

Mark only one oval.

	1	2	3	4	5	6	7	
Starke Ablehnung	◯	◯	◯	◯	◯	◯	◯	Starke Zustimmung

27. **In gemeinsam bearbeiteten Karten ist es hilfreich einen Überarbeitungsverlauf zu sehen** *

Der Überarbeitungsverlauf zeigt, welcher Nutzer wann Änderungen an der Karte, oder an Objekten vorgenommen hat

Mark only one oval.

	1	2	3	4	5	6	7	
Starke Ablehnung	◯	◯	◯	◯	◯	◯	◯	Starke Zustimmung

28. **Die verschiedenen highlight Farben haben mir geholfen zu erkennen welcher Nutzer ein Geoobjekt bearbeitet hat** *

Mark only one oval.

	1	2	3	4	5	6	7	
Starke Zustimmung	◯	◯	◯	◯	◯	◯	◯	Starke Ablehnung

29. **Das Anzeigen des Kartenausschnitts von anderen Nutzern hat mir geholfen die Anwesenheit von anderen Teilnehmern besser wahrzunehmen.** *

Mark only one oval.

	1	2	3	4	5	6	7	
Starke Zustimmung	◯	◯	◯	◯	◯	◯	◯	Starke Ablehnung

30. **Ich glaube, dass durch die echtzeit Synchronisierung die Aufgabe effizienter gelöst werden konnte** *

Mark only one oval.

	1	2	3	4	5	6	7	
Starke Ablehnung	◯	◯	◯	◯	◯	◯	◯	Starke Zustimmung

31. **Nennen Sie andere Anwendungsfälle oder Szenarien, wo echtzeit Synchronisierung von Karteneditoren hilfreich sein könnte**

....

....

....

....

....

32. **Nennen Sie die 3 Funktionalitäten, die ihnen am besten an dem Editor gefallen haben** *

....

....

....

....

....

33. **Nennen Sie die 3 Funktionalitäten, die ihnen am wenigsten an dem Editor gefallen haben** *

....

....

....

....

....