Designing Graphical User Interfaces for 3D Atlases

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Abstract. A well-designed graphical user interface (GUI) is crucial for the success of digital atlases aiming at a broad consumer audience. Hence, the design process has to be carefully planned and executed from the beginning of the atlas project. In this paper, an approach based on Interaction Design (IxD) is presented to efficiently create and implement a responsive atlas GUI. Four main IxD process phases are outlined, helping to assign the different design steps and tasks to a manageable workflow. To demonstrate the feasibility of the approach, the main phases of an atlas IxD are illustrated by GUI snapshots of the *new 3D Atlas of Switzerland*.

Keywords: 3D Atlas, Graphical User Interface, Interaction Design

1. Introduction

A graphical user interface (GUI) is an essential part of every interactive atlas. However, designing a user-oriented smart GUI for atlases is a challenging issue because of the inherent complexity of atlases. The complexity is not only related to their thematic content (information, scale, graphics), but also to their functional structure, and to a user community they have to consider. Though usability principles exist for decades (Nielsen 1993), most of the atlas authors still lack specific knowledge, experience and skills to create effective atlas GUIs. Moreover, GUI design issues are often discussed too late and revised only in the final phase of atlas production. Designing and implementing an atlas GUI involves not only atlas authors but also IT and Web specialists, and graphic designers. Therefore, it is highly recommended to follow a structured approach.

In order to efficiently design an adaptive atlas GUI, an approach based on Interaction Design (IxD) is presented. Compared to previous GUI design approaches, this approach is not only user-oriented, but also process-

oriented. Thus, GUI design is understood as a communication process on a graphical level and is incorporated into the realization process from the very beginning. In the following chapters, an overview of applicable techniques and tools of the whole atlas GUI design process is given, together with some recommendations on their use and impact. Although based on the experience of developing an online 3D Atlas of Switzerland, the approach is also valid for a majority of digital atlas projects.

2. General Principles, Concepts and Processes for GUI Design

The proposed atlas GUI design method is predicated on general principles and concepts of User Centered Design (UCD) and Interaction Design (IxD). While UCD focuses on the interaction process between the user and the product interface, IxD mainly concentrates on planning and designing the general functionality of the GUI, the properties and behavior of the GUI elements, and the graphical design of the atlas and the incorporated maps.

Principles of UCD were mentioned by almost every famous designer like Tufte (2001), Nielsen (1993), or Shneiderman (1998). In fact, the key messages are to know the user as profound as possible, and to enable the application to act consistently, making reasonable user action possible. For the development of an atlas GUI, this means to conduct user studies under realistic conditions in order to provide reliable feedback. It is also stated as important principle to minimize the cognitive load on users, and to balance user guidance and freedom. Here, information access strategies as well as the technical and graphical design of an atlas GUI are addressed.

The *process of UCD* can be subdivided into five stages: 1) strategy, 2) scope, 3) structure, 4) GUI skeleton, and 5) GUI surface (Garrett 2002; cited in Tsou & Curran 2008). In case of an atlas, every process stage has to be supported by several specific techniques and tools. At the *strategy stage,* atlas objectives and specific user needs are elaborated, whereas the functional specification of the atlas and its interactivity level has to be framed at the *scope stage*. Relations between GUI und 3D atlas engine, e.g., 3D navigation and picking functions, have to be considered also in this second stage. At the *structure stage,* a formalized function list in combination with a feature dependency schema can be applied to define the internal atlas structure. At the *GUI skeleton stage,* atlas functions are arranged by groups and visualized by sketches and wireframes. At that point, the overall GUI layout has to be determined. The *GUI surface stage* concludes the interface-building process. Only in this last phase, the graphical design of the overall look-and-feel and the individual GUI elements are elaborated.

The *process of Interaction Design IxD* represents rather the designer's view to develop the GUI. According to Spies (2012), who focuses on a holistic view in his book about Branded Interactions (BIxD), five creative phases can be distinguished: 1) discover, 2) define, 3) design, 4) deliver, and 5) distribute. *Discover* means to get knowledge of the market, the brand, the target group, as well as to set goals by means of a target matrix. *Define* stands for planning the communication, the product and service, and also the user experience. Based on these planning decisions, the strategy and the action plan can be determined. *Design* reveals the main design direction of the product where the typical "look and feel" of the application can be proved. The design phase is two-fold: the first part results in the Design Direction Presentation (DDP), where the information architecture and the visual vocabulary are presented. In the second part, a description of all design modules is worked out, resulting in a Detailed Design Documentation (DDD). *Deliver* refers to the compilation of a style guide and user experience guidelines. Additionally, the production of the GUI is accompanied by the DDD in order to launch the project. *Distribute* as the last phase of the IxD process is designated to introduce and implement IxD specifications within the team and the corporation.

A more specific description of the *IxD process* is given by different authors (e.g., Moggridge 2007, Herczeg 2006, Saffer 2006). In fact, they point out six successive stages:

1. *Investigation:* Search for similar products and novel technical approaches; use survey techniques (observation, questionnaire, etc.) to find out user profile and user needs; check economic aspects.
2. *Analysis and conception:* Analyze the user requirements; build concepts by means of creativity techniques (brainstorming, semantic intuition, brainwriting, etc.); define personas (user profiles), scenarios, and use cases to create interaction procedures as mock-ups and animations; set a vision statement to define the goals of the project.
3. *Creation of design versions and evaluation:* Design screen-flows to support the general concept and ideas; evaluate and improve the design versions iteratively.
4. *Prototyping and usefulness tests:* Apply three techniques (task and function, look and feel, feasibility) for prototyping, create horizontal and vertical (functions, depth of the application) prototypes; test the usefulness, measure the qualities of utility (features provided) and usability (ease-of-use).
5. *Implementation and realization:* Monitor the implementation process; ensure co-operation between graphic designers and software engineers.
6. *Final tests:* Test usability and correct bugs.

Although these three goal-oriented UCD and IxD processes differ slightly both in general and within every specific GUI project, they share several important principles:

- GUI design has to be strongly user centered
- The GUI design process has to start from the very beginning of the project
- The development has to be iterative-incremental, meaning that the GUI is improved in several cycles
- Prototype testing is a must in different process phases, not only at the end of the project.

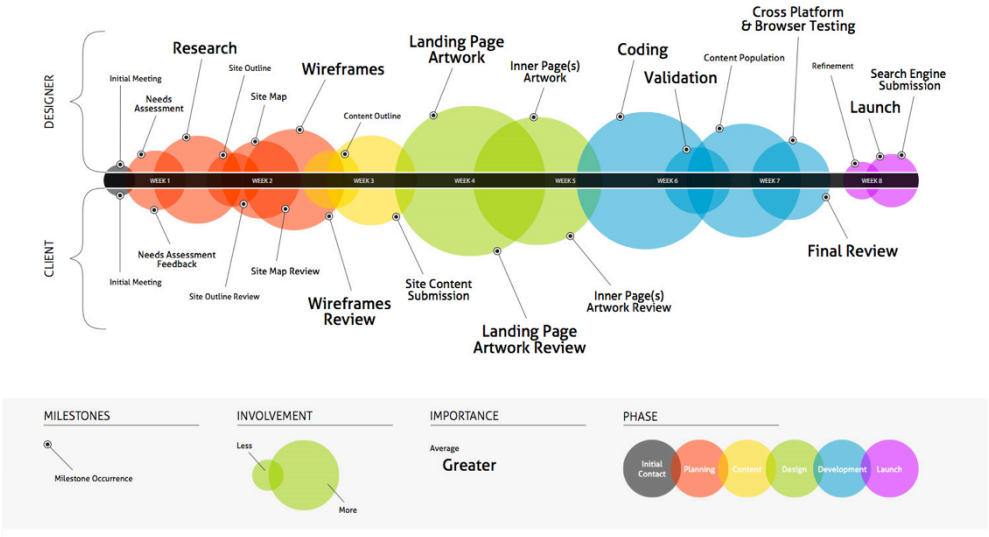

Figure 1. Overall conceptual model of an IxD approach (Armen 2014).

These general principles and processes serve as a profound background helping to design an atlas GUI with 3D content. In general, UCD and IxD approaches are regarded as being suitable for online products (*Figure 1*) and for digital atlases. But still there are some questions left: How can these principles be applied to an atlas project? And if the atlas contains 3D content: Do 3D maps require a special GUI, or at least specific functions? To clarify these questions, concepts and a more specific workflow of GUI design are presented in the following sections.

3. Conceptual Considerations of Atlas GUI Design

Designing an atlas GUI is a rather challenging task in many ways. For atlases with a broader scope such as national atlases, the target audience is heterogeneous in terms of thematic interests and technical skill levels. In order to bring the information to the user in a guided way, the incorporation of Narratives or Story telling (Caquard & Cartwright 2014) should be debated. Furthermore, the specification of the type of data and type of visualizations has to be set.

Another aspect is the general understanding and definition of the atlas concept, meaning that an atlas should unite different topics under a coherent GUI umbrella. This causes conflicts to its usability, due to a sub-optimal functionality and often little tailor-made GUI design for different types of maps. Nevertheless, the unifying atlas concept has advantages, as e.g., for map comparison tasks. Agreeing on this unifying atlas definition, other more technical settings have to be specified: Does the atlas structure allow for multi-use, and does it allow for 3D map visualization and manipulation?

Rather than to create an immersive 3D GUI as it is done in gaming environments (Bowman et al. 2012), an efficient atlas GUI design should concentrate on the seamless integration of 2D and 3D techniques. This can be achieved by a GUI based on the WIMP paradigm (Windows, Icons, Menus, Pointer) or by an interface based on direct touch, such as multi-touch tablets (Wigdor & Wixon 2011). Also, atlas GUI design depends heavily on the decision, whether an application should work on desktop computers, on mobile devices only or on both. Thus, the concept of GUI responsiveness (Marcotte 2011) is important.

Besides, atlas authors can choose from a big offer of interactive functions (Cron et al. 2007). Since the atlas GUI is heavily influenced by the number of functions, their degree of interactivity and hierarchical structure, the general setting of the atlas functionality has to be defined at an early stage of GUI design. Concerning dimensionality, decisions have to be made about the integration of temporal data and the treatment of 3D content. While temporal functions (e.g., a time slider) should be considered in every atlas GUI, 3D content should be handled differently. Within the 3D scenery, the task of spatial navigation – for exploring, searching and maneuvering at ease – is the most prevalent user action (Bowman et al. 2000). Selection and manipulation of objects in a 3D map can be identified as further 3D interaction techniques affecting the atlas GUI.

These conceptual issues have to be taken into account – and intentionally written down in an overall *Atlas Concept* – before the GUI design process is started.

4. The Process of Atlas GUI Design

As it turned out by considerations in previous chapters, the design process to create an atlas GUI will be based on the IxD approach, but slightly adapted to the atlas needs. Basically, the process can be structured in four main phases: *1) Investigation, 2) Rough Design, 3) Detailed Design, and 4) Implementation*. To underpin the atlas GUI design process, the different stages are exemplified by GUI elements of the *new 3D Atlas of Switzerland*.

4.1. Investigation phase

The investigative phase hooks on the overall Atlas Concept and incorporates state-of-the-art GUI and specific requirements. The intention of this first design phase is mainly to widen the authors' horizon by getting an overview of possible GUI solutions from related fields. Subsequently, the basic GUI structure by means of UCD techniques is defined. Below, the single steps and tasks are discussed more in detail.

- **State-of-the-Art Investigation**
  The process of IxD starts with a brief analysis of competitor studies, similar products and good GUI design examples. As an outcome, a cross board can be generated which identifies relevant features and evaluates them according to their usefulness for the planned atlas.
- **General Requirements**
  Preferably, a reference design is chosen which the atlas layout will rely on. Technical issues, like compatibility and responsive design of the GUI, but also graphical issues, like the question of using vector and/ or raster graphics, have to be discussed. The outcome of this step will be a setup of general affordances.
- **Use cases**
  According to the User Centered Design, user groups and profiles ("persona"), scenarios and activities have to be defined. As a result, characteristic tasks and actions are recognized, leading to a better layout prioritization of the design elements.
- **Interactive Functionality**
  To complete the investigation phase, the functionality of the static and dynamic atlas GUI features (icons, tools) has to be elaborated. Features belong to well-known groups such as general atlas functions, spatio-temporal navigation, thematic navigation, information and didactics, visualization, and analysis. The result is a schematic listing or sketch of all planned atlas UI-elements, showing their interactions, dependencies, and behavior.

The new 3D Atlas of Switzerland (AoS) started with a comprehensive ten-years atlas concept (Sieber et al. 2011), where the general cartographic approach and also the Vision Statement are designated. During this conceptual phase, the decision has been made to collaborate with a design company specialized in IxD. State-of-the-art studies of web atlases, geoportals, and virtual globes were then conducted. To gain experience with mobile devices, IxD students designed clickable prototypes for tablets, based on material from the former AoS 3. An additional survey with "Digital Natives" (Schnürer et al. 2015) took place to reveal hints concerning optimal atlas GUI layout structures for desktop applications, but also to learn more about the behavior of the young generation as a target audience (*Figure 2*). The evaluation of atlas reference designs resulted in choosing Windows 8 Metro as a basis; a mock-up was created to proof its' feasibility. In the following, different use cases were formulated, including persona (pupil, student, teacher, journalist, retiree, hiker, tourist; differing in age and expertise in geography), scenarios (education, work, leisure time), and activities (e.g., comparing map layers, adding own data, customize the map). Finally, a list of basic and advanced atlas functions was defined. Since the next AoS edition will concentrate on visualizing and exploring 3D maps, only a limited number of functions is taken into account, as, e.g., to search for locations and themes, to show the current position, to relocate, to set the time, to pick map information, to measure distances and areas, and to show multimedia elements.

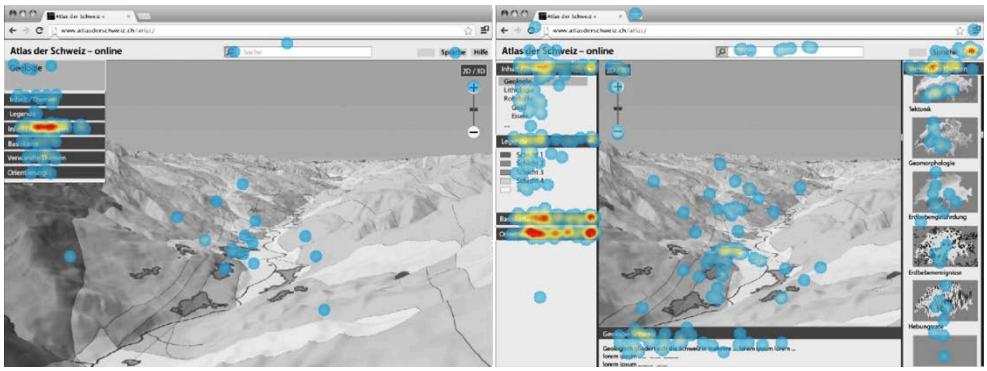

Figure 2. Survey on desktop atlas GUIs: Students were asked to get additional information about a map topic. The resulting surface density maps show clustered (left) or scattered click patterns (right) for the same task depending on GUI layout (Schnürer et al. 2015).

4.2. Rough Design phase

The rough design phase ranges from the definition of general framework over an operating workflow sequence to a dedicated GUI specification. Using different prototyping techniques, potential graphical pitfalls, and structural dead-ends can be identified and hopefully avoided. Screen-flows and try-out-versions are produced to get a visual impression, but also to test the interactive behavior of the GUI. The aim of this second design phase is to compose sketches of a coherent, well-working atlas GUI and to agree on a distinct design direction.

- **Wireframes**
  Sketching and wireframing techniques are applied to define a storyboard. By means of this storyboard, a run through sequences of actions can be tested easily and improved with low effort. At the same time, the hierarchical structure of the GUI with layout prioritization of the design elements should also be looked at. The resulting document will be a storyboard of all relevant actions and statuses occurring in the atlas.
- **Moodboards**
  Moodboards – also called artboards – reflect the main design direction of the product. Here, the "Look and Feel" of the atlas is defined. This comprises not only color schemes and styles, but also the arrangement of GUI elements in various showcase layout versions, as well as object animations and actions. It is important to judge these elements in combination with map design. The goal of this process phase is to get a vivid impression of possible design styles and to ease the decision on layout and graphics.
- **Overall GUI Design**
  During the last step of the rough design phase, a number of main screens is created. Usually, two or three main screen examples are sufficient to cover the most typical GUI elements of an atlas. These exemplary main screens help to demonstrate the responsive concept for flexible multi-use of the atlas on different screen sizes and media. Decisions on general screen layout, typography, leading colors, etc. have to be represented in accompanying documents. It is also recommended to follow a rapid GUI prototyping approach to test the atlas usage and to clarify roughly the technical feasibility of the proposed atlas GUI. Results of this phase endorse the general design direction.

  Design Direction Presentation (DDP)
  The DDP leads to a final decision on graphics and behavior. It has to be approved for release by the customer.

The rough design phase is crucial for the whole atlas project. It is likely that users stay longer on an atlas web site if the overall GUI design is appealing. Thus, an iterative evaluation and improvement of the overall design versions is highly recommended.

The new 3D Atlas of Switzerland follows the track outlined above. A kickoff meeting with the graphics designer was organized to provide them with background information to the AoS project, and more specifically, to present all materials from the Investigation phase. During the next weeks, numerous versions of wireframes and moodboards (*Figures 3 and 4*), including fonts and color schemes, were created, accompanied by immediate feedback loops. Muted colors were chosen and icons kept in a minimalistic-figurative style, in order not getting sidetracked by details. Overall GUI design was applied on two main screens, the start screen and the map screen.

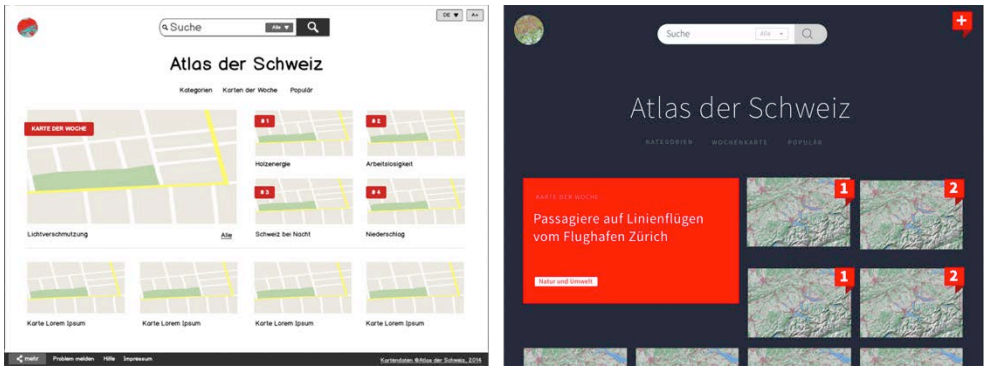

Figure 3. Wireframe (left) and moodboard (right) of the start screen of the 3D Atlas of Switzerland.

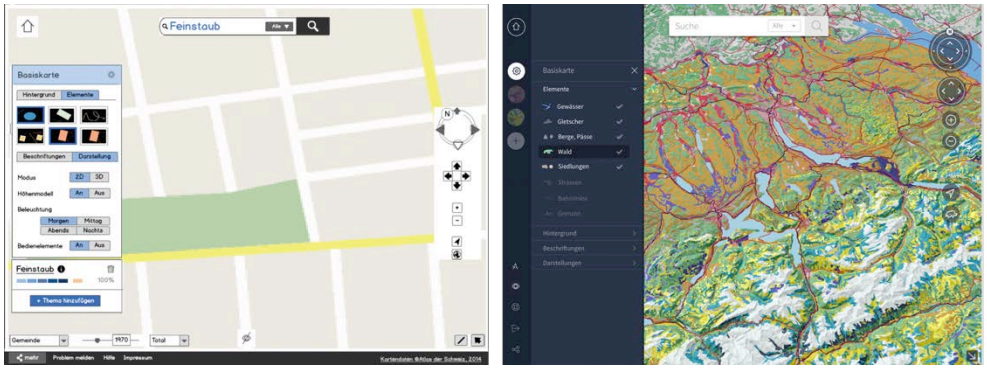

Figure 4. Wireframe (left) and moodboard (right) of the map screen of the 3D Atlas of Switzerland.

4.3. Detailed Design phase

Once the main direction is approved and accepted by the involved parties, the detailed design can be worked out. Only slight changes of GUI design are envisaged during this phase. The intention is to get a clean graphical GUI layout and an interaction plan for further implementation.

- **Detailed Design**
  Different screen layouts and single GUI elements have to be drawn or painted. Structural elements of the GUI like windows, icons, controls, as well as GUI interaction elements representing statuses (cursors, buttons), interactions (e.g., clicks), and animations (e.g., slide) are designed. Small corrections of color and element placement are carried out. The achievement of the detailed design step is the final artwork, which should not be modified anymore.

- **Design Specifications**
  The final artwork has to be prepared for technical implementation: precise dimensioning and definition of all GUI elements and layouts has to be done, following the principle of "atomic design" (from smallest elements to largest ones). Another deliverable is the specification of statuses and interactions. The output of this phase is the Detailed Design Documentation.

  Detailed Design Documentation (DDD)
  The DDD marks the end of the graphical design process within IxD. It serves as reference document for the implementation phase and contains the dimensions and behavioral description of every GUI element.

The new 3D Atlas of Switzerland features some special cases in the detailed design phase. Layouts were created for different pages such as maps of the week, thematic categories, quick search (*Figure 5*) and advanced search, help and imprint. More specific layouts were designed for different panels such as add/export map, map details and infos, display settings, and measure tools. Animated sequences illustrated transitions from the start screen to the map screen and vice-versa. The GUI controls are drawn as vector objects in order to preserve a sharp image when GUI size is scaled. The detailed design of icons started from an existing icon library to save time and costs. And finally, the description of statuses (on/off) and interactive functions (e.g., distance measure tool; *Figure 6*) was always accompanied by pictorial examples, because a textual description could be misleading for software developers.

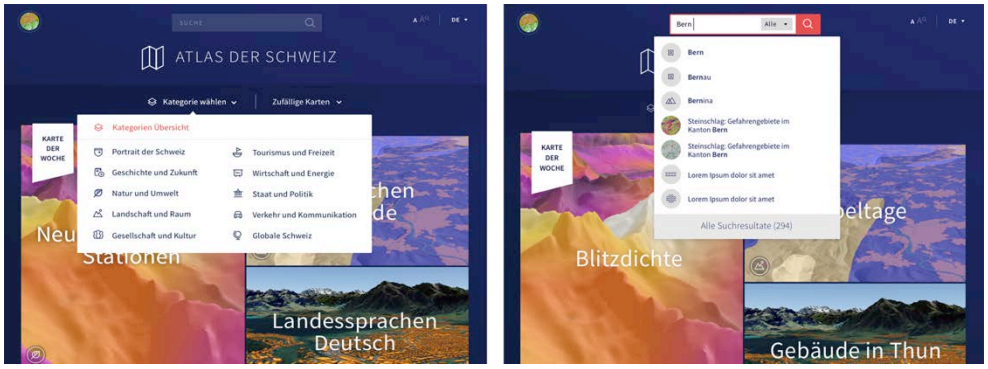

Figure 5. Detailed design of the start screen with main categories (left) and quick search (right) of the 3D Atlas of Switzerland.

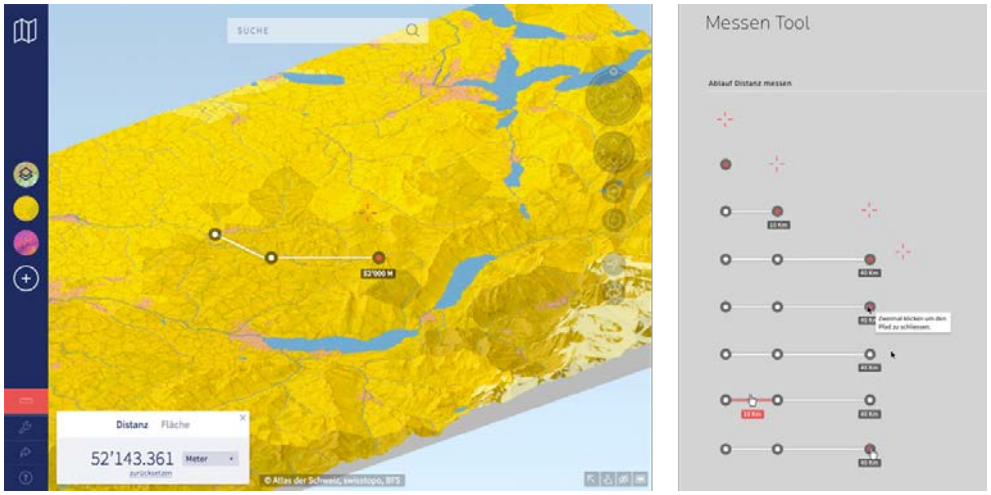

Figure 6. Detailed design of the map screen (left) and specifications of the distance measure tool (right) of the 3D Atlas of Switzerland.

4.4. Implementation phase

The last phase of the atlas GUI design process covers the technical implementation of the detailed design. In order to ensure a mutual understanding, the GUI designer, and the atlas authors should closely accompany the process. The goal of this phase is to build an operational GUI that could be used by different atlas versions.

- **Implementation of GUI Design Specifications**
  The programming of GUI elements and their behavior (statuses, interactions and animations) should be delegated to specialized developers, such as front-end web developers. Requirements of different operation systems, browsers, devices and display environments have to be specified for them.
- **Implementation Testing**
  For individual atlas components, intense functional testing has to be conducted. It is desired to fix bugs immediately to have working snapshots of the application available for further development and testing.
- **Usability Testing**
  Testing the usefulness and usability of the atlas GUI certainly ameliorates the atlas handling, but has influence on the technical implementation, too. Potential atlas user groups were asked to check the functionality and to "play" with the atlas content. Thus, the integration and smooth usage of functions can be evaluated.

  Operational GUI
  The final result is a technically thin, robust and scalable GUI, working swiftly under different conditions. Ideally, the GUI assists atlas users in performing the tasks without coming to the fore.

For the new 3D Atlas of Switzerland, one of the main goals of GUI implementation is to keep GUI resources low in order not to impede the rather complex 3D visualization processes. Therefore, a list of applicable technologies and deliverables has been defined according to the agreement with the IxD company.

Since the atlas should run firstly in a Desktop environment, and later also on Mobile devices, gesture controls has to be supported. The *Chromium Embedded Framework (CEF)*[1] served as a browser environment, while as a JavaScript framework *vue.js*[2] was chosen. To guarantee a neat communication with the atlas back-end and its 3D visualization engine, data models and event interfaces were defined. Otherwise, IxD front-end developers had free choice of CSS extension language; they decided to work with *SASS*[3].

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[1] https://bitbucket.org/chromiumembedded/cef

[2] http://vuejs.org/

[3] http://sass-lang.com/

Github[4] was used as a code repository in order to examine the implementation progress in regular time sequences.

Finally, the deliverables were defined, consisting of basic structure and modules (single page layout, icon system, standard dropdown and buttons, etc.), content modules (search results, multimedia information, overlays, etc.), GUI modules (icons, dropdowns, buttons), animations (page, icon hover effects, etc.), and interfaces for the GUI components. After every module delivery, implementation testing is done as an iterative improvement process. To conclude this last phase, usability testing will be undertaken with groups of current AoS 3 users and atlas novices.

5. Conclusions

The atlas GUI is the all-embracing gateway to maps, attributes, tools and multimedia content. Although the atlas is organized internally in a rather complex structure in terms of thematic content and interactivity, the atlas GUI should provide an easy, seductive access to the maps. Therefore, the GUI design process should start in an early phase of the atlas project. As proven by means of the Atlas of Switzerland, the IxD approach is very promising for atlas projects, even in combination with a virtual globe as a 3D visualization engine. Future GUI extensions, e.g., special analysis tools, are still possible.

Still missing in the context of atlas GUI design are layout shells for different types of atlases. Here, an open toolkit to combine functions, e.g., by piping, could be realized. Interfaces based on direct touch used for mobile devices still bear a great potential, e.g., for outdoor usage. Atlas GUI design could also experiment with so-called Natural GUI (NUI), which are used in gaming environments. They allow for immersive actions, providing the user with more affective experience.

[4] https://github.com/

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