# Analyzing the Usability and User Experience of an Adaptive Geographic Information System

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## Abstract

User interfaces which adapt to user tasks, behavior and preferences are expected to be better than non-adaptive interfaces. However, so far few data is available to quantify the effect adaptivity has on usability and user experience. In this paper, we analyze this effect for a professional geographic information system. In a closed-group between-subject experimental design with expert users, we compared an adaptive and a non-adaptive version of the system with respect to effectiveness, efficiency, and attractiveness. The results show that a smart adaptation of the information presentation can increase effectiveness and efficiency as measures of usability, but did not significantly affect user experience.

**Index Terms**: graphical user interface, adaptivity, user model, usability, user experience

## 1. Introduction

Graphical user interfaces (GUIs) are a standard for most computer programs. Nearly all such interfaces are optimized regarding *how* to present information, whereas providing the user with relevant *personalized* content is just as important [1]. Users differ in what interests them, even if their goals are similar; thus, user interfaces should be able to adapt to the particular tasks, behavior, and preferences a particular user has. It is expected that such an adaptive user interface will offer a better usability and user experience compared to a non-adaptive interface, although quantitative data on the size of this effect is rare.

The need for customized content leads to the problem of user models, which represent a collection of relevant data of a specific user, and will serve as a basis for changing the behavior of the system to better meet the needs of this user. User modeling became interesting because the user models have the potential of improving the collaborative nature of human-computer systems [1]. According to [2], an adaptive user interface is a software artifact that improves its ability to interact with a user by constructing a user model based on a partial experience with that user. This definition implies that an adaptive user interface does not exist on its own – the user has to interact with the interface, and the interface improves further interaction based on the collected data. As a result, an adaptive user interface is a specialization of a learning system, a fact which has to be considered when assessing the effect adaptivity has on the interaction behavior, and on system usability and user experience.

It is the aim of the present paper to quantify the effect adaptivity has on several aspects of usability and user experience. For this purpose, we selected a professional geographic information system as an example of a user interface which has a strong information presentation aspect, and which has a professional user group who frequently interacts with the system, so that a proper user model can be created, and that the user group would take a large profit from any improvements of interaction behavior the adaptivity might provoke.

The paper will be structured as follows. First, we will present an outline of the geographic information system and the strategies which have been followed for its adaptation in Chapter 2. In Chapter 3, we will describe the set-up and run of two experiments in which the effects adaptivity might have on effectiveness, efficiency and system attractiveness have been quantified. The results are analyzed and discussed in Chapter 4. Finally, Chapter 5 summarizes the findings of the paper and draws a perspective for future work. The paper is based on the results of a Master thesis performed by the first author [3].

## 2. Geographic information system

The Web-based Geographic Information System (WebGIS) is a tool used by banks, insurance companies and other businesses that evaluate real estate all over Germany. Users can navigate to any location in Germany either by using the search bar or the map and the crosshair, and the tool provides the user with useful information about the selected address or regional unit. This includes regional geographic information, the latest official statistics, several map overlays, and reports from a number of real estate associations and other reporters.

The user interface of the tool consists of four main parts, see also Fig. 1:

1. The Header on the top of the page which contains the name of the selected regional unit, the search bar, the navigation bar and the user menu;

2. the Map in the center of the page which shows the selected location;

3. the Data Panel on the right which displays the data the user is working with;

4. the Options Panel on the left which can be used to disable such pages that the user is not interested in, or turn on and off additional map features.

Since the Data Panel is the main area in which the user works, the adaptive features will be applied here.
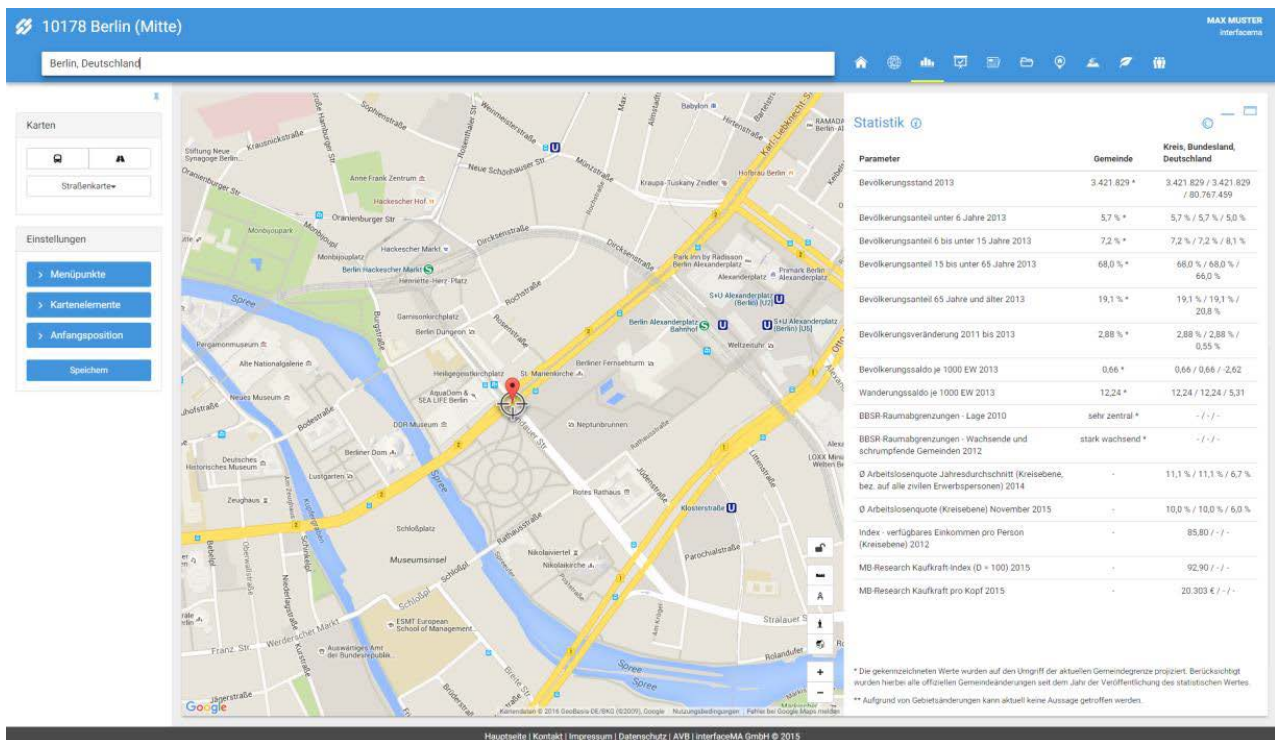
Figure 1: Screenshot of the GUI of the Web-based Geographic Information System (WebGIS).

For the adaptation, we used a split menu strategy originally proposed by [4] and combined it with highlighting [5], see Fig. 2. This strategy was selected because we wanted to ensure that items that are not part of the recommendation should not be hidden, the recommended items should stay at approximately the same place in the document structure, and the appearance of the recommendations should be as consistent as possible on all the pages. We applied this adaptivity principle to six different pages of the Data Panel, in order to ensure that it can be meaningfully generalized to a number of different tasks and task items.
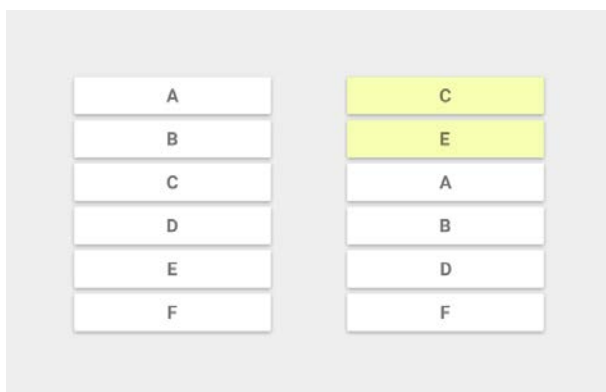
Figure 2: Adaptation strategy used for the list menus.

## 3. Experimental design and set-up

A two-step experimental design was chosen to address the problem. In an initial user study we collected quantitative and qualitative data about the work context of the users in general, and their habits regarding the WebGIS. Also, this study helped us in identifying user groups - based on how often and for what purpose they use the product - in order to refine the list of features of the adaptive user interface. Finally, the user study helped us in identifying appropriate users for the final user test that was conducted after the implementation of the adaptive user interface.

In the follow-up experiment, the impact of the adaptive user interface was measured in a controlled way with pre-defined typical tasks. These tasks were defined using the collected data from the initial study, and by involving task experts (former employees of the company) to ensure the relevance of the formulated tasks. Six tasks of differing complexity were defined, each consisting of a geographic unit (or exact location) and a question that had to be answered by the user. A prototypical task looks as follows:

*Address*: 45141, Essen, Germany ("Deutschland")

*Task*: Navigate to the ZIP-code area, and find the average area of the residential buildings ("Wohnungsgröße") in 2013, based on the LEG report. Compare it to the average value of the federal state (NRW).

Each task was then triplicated in three varieties, with different task details (e.g. different geographic locations). The resulting 18 tasks were organized in 3 blocks with 6 tasks each.

Each participant had to complete 3 blocks that differed in what tool was allowed to be used. For each of the blocks, the users had to use either a third-party tool, the WebGIS tool, or they could choose between the third-party tool and the Web-GIS tool. 10 users participated in the experiment who were associated to one of the two groups (*Group A* and *Group B*), balancing out for their experience with the system, their role in the company, and age and gender, following a between-subject design. Participants in Group A used the non-adaptive version of the Web-GIS, while users in Group B got the adaptive version. The experimental design is outlined in Fig. 3.

| Product | Group A | Group B | |
|---|---|---|---|
| Third-party tool | Block A1 | Block B1 | |
| WebGIS | Block A2 | Block B2 | adaptive WebGIS |
| Free to choose | Block A3 | Block B3 | adaptive WebGIS |

Figure 3: Design of the user test.

As quantitative metrics for the effect of adaptivity, we used an expert evaluation of the correctness of task solution (for effectiveness), the task completion time and the cognitive workload measured with the Raw NASA Task Load Index [6] (for efficiency), and the AttrakDiff questionnaire [7] quantifying pragmatic and hedonic quality aspects (for user experience). The expert annotation of the correctness of task solution was carried out assigning 1 point for a correct solution, 0.5 points for a partially correct solution, and 0 points for an incorrect solution or a failure of retrieving any information from the system. The task completion time was measured with a stopwatch. Whereas correctness of task solution and task completion time are unidimensional indices, the Raw NASA Task Load Index and the AttrakDiff questionnaire are multidimensional metrics which potentially can provide more insight into reasons of observed differences.

For each task, the test participant first had to read the task description. The task description was available the whole time, and the user could also ask for clarification before starting to resolve the task. When the task was clear for the test participant, the experimenter instructed him/her to start with the solution. At this moment, the researcher started the stopwatch that measured the task completion time. When the user indicated that he/she was done, the researcher stopped the stopwatch and evaluated the solution, as mentioned above. The task completion time and the points for the effectiveness were registered in a form on a computer. Finally, the participant was asked to complete the NASA Task Load Index Questionnaire [6], and then received the description of the next task. After finishing the last task, the test participant was asked to evaluate the overall experience of the WebGIS with the help of the standard AttrakDiff Questionnaire [7] in their preferred language (German or English).

## 4. Results

The results have to be considered with care as they stem from a quite limited number of users. This restriction was due to the level of expertise we required for having "typical" (i.e. professional) users; thus, within the limit of the resources available for a Master thesis, we preferred to collect rather few data from a small number of typical users than collecting more

data from a user group which would not be representative for actual system users.

In total, the 10 participants completed 30 sessions - 3 blocks per user. Each participant received 6 tasks to complete per session. For each task 8 values were registered: the points given for the effectiveness, the task completion time (in seconds), and the 6 aspects of cognitive workload defined by the Raw NASA Task Load Index questionnaire: mental, physical and temporal demand, performance, overall effort and the perceived frustration.

The gathered data was compared between the 6 blocks to analyze the differences between the user groups, the change in usability and user experience between the WebGIS and the third-party tools, and finally, the effects of using the adaptive version of the WebGIS compared to the non-adaptive version.

First, the results obtained for the third-party tool were used for analyzing differences which might stem from the assignment to the two participant groups. A one-way ANOVA did not reveal any significant differences for any of the effectiveness and efficiency-related variables.

Second, the non-adaptive version of WebGIS is compared to the third-party tools in order to illustrate the overall level of usability and user experience of the tool under investigation in comparison to an exemplary other tool. Regarding effectiveness, no difference was observed. Although the means of expert-annotated correctness of task solution of the two groups were 0.83 for the third-party tool and 0.92 for WebGIS, this difference is not significant ($p = 0.353$). However, task completion time and cognitive workload were significantly lower for WebGIS compared to the third-party tool. The average cumulative task completion time has decreased from 598 s to 311 s, which is a significant change ($p < 0.001$), see Fig. 4. For the cognitive workload all dimensions showed a significant difference on the $p < 0.001$ level, except performance for which the difference was borderline ($p = 0.051$), se Fig. 5.
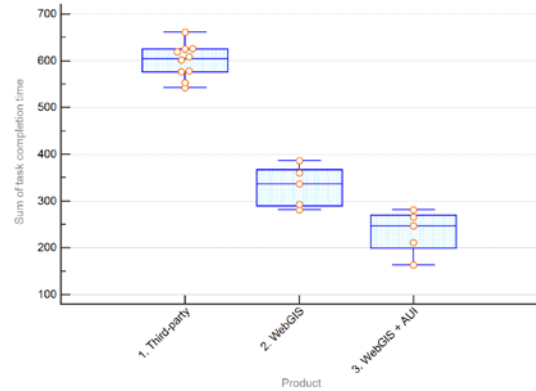


Figure 4: Task completion time accumulated over all three tasks, per system version.

When comparing the adaptive and the non-adaptive version of WebGIS (marked as "WebGIS + AUI in Fig. 4 and 5), effectiveness showed a significant improvement in the adaptive version, and the mean correctness value of task solution changed from 0.92 to 1.0. In addition, also the task completion time as one measure of efficiency could be significantly reduced with adaptation ($p = 0.01$). The average user of the non-adaptive version completed the tasks in 331 s,

while participants using the adaptive version needed 234 s. Taking task load as an efficiency measure, the picture is less homogenous: Mental demand, physical demand, temporal demand and frustration of the Raw NASA Task Load Index were left unchanged (all $p > 0.05$), whereas the ratings of performance ($p = 0.028$) and or overall effort ($p = 0.018$) were significantly improved compared to the values observed for the non-adaptive version of the WebGIS.
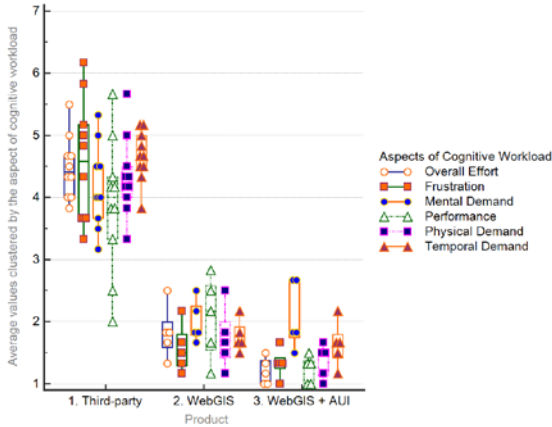


Figure 5: Average values of the Raw NASA Task Load Index, per system version.

Regarding user experience, both the adaptive and the non-adaptive version of the tool scored in the upper right "desired" corner of the result chart, revealing high pragmatic (functional) as well as hedonic (non-functional) user experience for both tools, see Fig. 6. No significant difference was observed between the system versions.
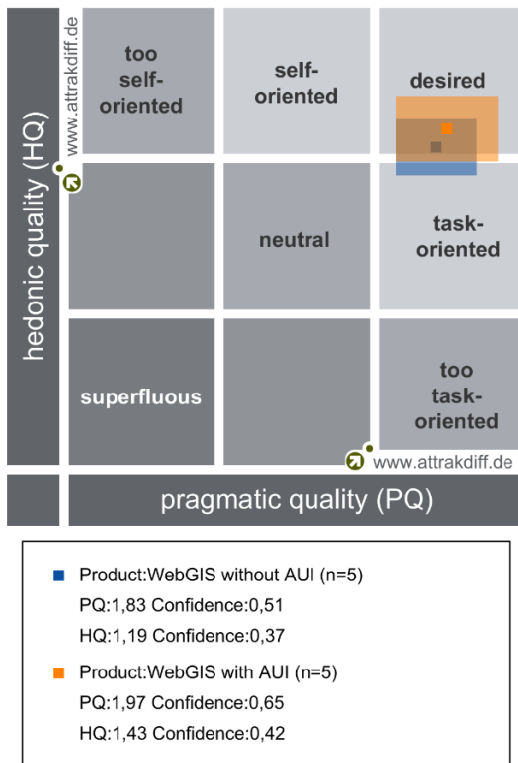


Figure 6: User experience ratings of the adaptive and no-adaptive version of WebGIS, following the AttrakDiff questionnaire.

When analyzing the blocks where test participants were free to select the tool, no significant difference was found between the adaptive and the non-adaptive version of Web-GIS. Most participants solved all tasks with WebGIS when they were free to choose, and only one participant of each group solved 2 tasks (out of 6) with the third-party tool, in addition to one participant of the non-adaptive group used the third-party tool for one task (out of six). This underlines the high overall rating of the WebGIS tool for our test participants.

## 5. Conclusions and future work

The results showed that both effectiveness and efficiency can be improved by adapting graphical user interfaces towards user requirements. Using the adaptive version of the WebGIS tool, our expert users could achieve a considerably higher effectiveness and a lower execution time compared to the non-adaptive version. The picture for the task-load related metrics was less homogeneous, showing improvements for some, but not all constituents of the Raw NASA Task Load Index. No improvement could be observed for the user-experience metrics collected with AttrakDiff; however, this may be due to a saturation of the metric, as both tools already scored in the upper right area of the result chart.

The results have to be regarded with care as the number of text participants was rather small, and as all of our test participants were already expert users of WebGIS. This limitation was accepted in order to have a representative group of expert users; however, follow-up experiments should show whether the results can be confirmed for a larger user group. In addition, it would be interesting to compare different adaptation strategies, using different ways to display the adapted (and potentially most relevant) information. It should also be investigated how the observed effects change with the amount of data the adaptation can be based on. Finally, we think that also expert users differ with respect to their requirements, in the sense of the items and criteria of the system they mostly work on; thus, adaptation strategies might take such topic-related differences into account.

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