Usability Evaluation of Web-Based GIS by means of a Model

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***Abstract*—Spatial information is required by many users to support their decision-making. Application that provide spatial information may be quite complicated so evaluation of their usability is very important. Usability evaluation can help to improve their design or how to choose better application. Many various methods have been proposed. The paper describes a case study which uses combination of usability user testing and NGOMSL model to evaluate usability of chosen Web-based applications by means of calculating a utility. Case study shows that very similar results are obtained by both methods. Average time necessary for usability evaluation is shorter in the case of NGOMSL model.**

Keywords—Usability; NGOMSL; user testing; Web-based GIS

I. INTRODUCTION

Usability of a user interface is the only quality characteristics focused directly on users and on ability of an application to meet users' requirements and needs. Usability is partly overlapping accessibility [15]:

- 'Pure accessibility' problems only affect disabled people
- 'Pure usability' problems only affect non-disabled people
- 'Universal usability' problems affect both disabled and nondisabled people.

There are two basic ways of usability evaluation [5]: formative and summative. Formative evaluation methods are used during the design stage (before releasing the final product). Formative evaluation is focused on identification of usability problems that should be solved during the design. It is recommended to use a combination of expert-based and user-based inspection methods for evaluation. Summative evaluation is focused on a final product or on a comparison of competitive design alter-natives [5].

Various usability evaluation and testing methods have been used in many studies to improve quality or to compare products. Lately, there can be seen an attempt to improve and enrich methods, e.g. by means of fuzzy logic [7], by involving cognitive modelling [12] or by utilization of eye-tracking [11]. Today, the term usability is being replaced by terms quality in use or user experience, which adds emotions of users. A new instrument allowing measurement of satisfactions of video games users can be given as an example. It aims at measuring of user satisfaction and gaming experience [16].

The main aim of the paper is utilization of a model for usability evaluation along with a user testing to identify problems in usability. Based on the results, used methods of usability evaluation will be evaluated from the point of view of obtained results. The paper describes a case study evaluating a universal usability of three chosen Web-based GIS applications. NGOMSL model and user testing are used as usability evaluation methods and their results are compared.

Structure of the paper is as follows: the second chapter describes used data and methods. Next, hypotheses and research questions are stated. Next chapter describes the proposed procedure. The following chapter provides answers to the research questions and hypotheses. Conclusion follows.

II. USABILITY EVALUATION AND TESTING BASED ON MODELS

Many various factors can influence usability and many factors have to be taken into account while making design easier and more usable. Analytical models can help in both design and usability evaluation because of complexity of the problem of usability.

Task models describe how activities can be performed to meet user's goals by means of an application. Task models allow designers to describe both provided functions and interaction between user and user interface. Thus, importance of task models has been widely recognized for a long time [14].

Importance of goal-oriented modelling was emphasized by [2]. Goal-oriented models should describe users' knowledge necessary to operate a computer and actions, which have to be done by users to reach the goal. Models for usability evaluation should describe the following aspects [2]:

- External tasks to be completed by users with help of software
- User knowledge necessary to use computer
- User performance necessary to delegate tasks to computer, both mental and physical

- The computer system as tool to support user and as a result of design

Utilization of a software means that there is an interaction between a user and a software going through a user interface. An interaction evaluation model has to identify the following facts [3]:

- Accessibility conformance by an objective-oriented observation
- All types of accessibility and usability problems by testing a mixed panels of disabled and non-disabled users with a subjective-oriented analysis
- User satisfaction in order to complete the subjective-oriented observation.

Various analytical models have been proposed for usability evaluation: some of them are based on GOMS method, e.g. NGOMSL, CPM, CMN or KLM; another is based on PUM method. Utilization of natural language belongs to NGOMSL advantages [6]. GOMS analysis was used to evaluate user interface for disabled users [17] and for visually impaired people in a modified form of GOMS as well [19] so it can be understood as a robust tool.

Several software tools have been developed to support utilization of GOMS, e.g. QGOMS, CATHCI and GLEAN3 [1], [8].

Late, cognitive modelling was introduced as a new approach how to improve usability evaluation. Cognitive modelling has evolved from task-analysis, e.g. GOMS, to better predict human performance. The study [12] showed a suitability of cognitive modelling for improvement of usability of a user interface.

III. CASE STUDY

The whole case study is focused on usability evaluation of chosen Web-based GIS applications of three regional authorities in the Czech Republic. The whole study is designed in a qualitative way, i.e. to identify serious problems in usability of the applications and to evaluate changes since the last evaluation. The study is designed to this purpose and it is split into 7 phases – see Figure 1. Existence of suitable and reasonably expensive procedures of usability evaluation of Web-based GIS is important because they are often outsourced. Quality monitoring of outsourced services is very important and requires suitable measures [17]. Consequently, usability of applications can influence success of e-Government services [10] from the point of view of acceptance of applications by citizens.

A. Phase 1 – Aim Definition and Choice of Evaluated Applications

Aim definition: to identify problems in usability of chosen Web-based GIS applications of regional authorities in the Czech Republic. As far as there are 14 authorities in the country and several studies were done previously, e.g. [9], it was decided to include only three of them in this case to see changes in design of applications. It was decided to include usability evaluation based on model because of scientific character of the study to allow identification of benefits of this type of methods.

Choice of applications for evaluation: at first, list of used software solutions is provided. Each software solution can provide similar applications so duplicate applications can be excluded.

Software solutions used to run Web-based GIS of particular regional authorities:

- ArcGIS Server: Jihocesky, Zlinsky, Stredocesky, Plzensky, Ustecky
- Hydrosoft Veleslavin: Pardubicky, Kralovehradecky
- Geocortex Essentials: Moravskoslezsky
- GeoMedia WebMap: Jihomoravsky
- Vars Brno: Karlovarsky, Vysocina
- T-mapy: Praha
- Maps only for download: Liberecky, Olomoucky

Next, a multi-criteria decision-making choice is done using the following criteria (all criteria are minimization ones):

- C1: Direct accessibility of administrative units map from the main menu
- C2: Similar range of functions of data which allows to use similar scenario for usability evaluation
- C3: Tools accessibility
- C4: Demandingness on users
- C5: Uniqueness of an application (its user interface)

An expert (one of authors) evaluated all applications and assigned points to all of them. The following application are chosen for usability evaluation during this case study:

- Pardubicky kraj (Hydrosoft Veleslavin)
- Moravskoslezsky kraj (Geocortex Essentials)
- Stredocesky kraj (ArcGIS Server)

They are based on different software solution including ArcGIS for Server, which is the most often used solution.

Usability evaluation is focused on the following common functions: scale; search tools; overview map; available layers; distance measurement tool; retrieval of an attribute information about a chosen feature; zooming and panning of a map; availability of information about an application.

Figure 1. Usability Evaluation Procedure (source: authors based on [4])

B. *Phase 2 – Choice of Methods*

The study aims to involving some representatives of users and wants to minimize costs so NGOMSL model is chosen. Main reasons of this choice are: a short time necessary to build the model; simplicity and understandability for participants; utilization of natural language; and suitability for evaluation of usability of Web-based GIS.

To verify results, a suitable method must be chosen which provides comparable results for reasonable costs. Time necessary to run particular operations is a key measure of NGOMSL so a method for results verification must provide time spent by users to fully or partly finish given tasks. Usability user testing is used because of the stated reasons as a verification method in this case.

C. *Phase 3: Choice of Participants*

Aim of the study is to identify serious problems in usability so the study follows Nielsen's approach – 3 to 5 participants are able to reveal about 85 % of problems in usability [13].

Choice of participants according to their availability belongs to often used methods. A representative set of citizens would be more interesting from the statistical point of view but this approach is quite expensive. So, some students of the faculty are used as participants in the case of this study. Only students before attending any GIS class are included into study. To speed up study progress students are involved in two roles: participants and evaluator's assistants. Amount of participants (and used order) must prevent an effect of learnability as well. It results into necessity of slightly more participants. In total, 12 participants are included to allow evaluation of all three web site by means of both methods in various orders.

D. *Phase 4: Necessary Tools and Equipment Preparation*

A computer lab with 21 seats and computers is used as a simple test-room. Thanks to its arrangement, 6 participants could obtain introductory information at the same time and they could simultaneously evaluate the applications. Because of a size of the room, they did not disturb each other. There are no requirements on a special room arrangement and on a video-recording.

Used PC: Dell Optiplex 380 Desktop with Intel Pentium Dual Core E5500 2.80 Ghz CPU, 2GB DDR3 RAM and Win 7 with SP1, 32-bit.

E. *Phase 5: Model Proposal, Scenario Definition and Verification*

The following main functions are included into usability evaluation: utilization of a scalebar, finding a feature by means of available search tools, utilization of data layers, distance measurement, identification of a feature and retrieval of attribute information about it, basic control functions: pan, zoom in, zoom out, and findability of an application by means of Web searching engine (e.g. Google).

The above listed aims are turned into set of particular activities to collect both performance and subjective (the last five items) data [4]:

- Findability of an application by means of Web searching engine
- Clearness of arrangements of main menu after starting Web-based GIS application
- Adjustment of scalebar/scale of maps
- Finding a required tool
- Utilization of particular layers (turning them on and off)
- Finding a required feature in map
- Utilization of zooming to display required area of interest
- Distance measurement between features
- Retrieval of attribute information about a feature
- Understandability of cartographic symbols
- Pleasance of a user interface
- Response time of an application
- Design (looking) of an application and its compliance with design of a "general" web site of a regional authority
- Necessity of plug-ins installation

Scenario for **user testing** contained 18 tasks in the beginning. Some tasks were excluded because of their difficulty or misunderstanding. On the other hand, there was added one task focusing on search tools. Some tasks were re-formulated and the Excel forms with tasks were prepared. The final list, after pilot testing, contains 14 tasks [4]:

1. Use Google to find the Web-based GIS application and its starting page. Choice of keywords is up to you
2. Find a map of administrative division of the region and open it
3. Set a scale to approx. 1 : 200 000
4. Find a tool "Undo/Back" for one step back action within map tools

5. Display layer containing municipalities with extended competence and turn all other layers off
6. Use any way to display name of one of municipalities with extended competence at a scale approx. 1 : 500 000
7. Find and use a tool to display full extent of the region (display all municipalities of the region)
8. Measure a direct distance between any two municipalities with extended competence
9. Use a suitable tool to retrieve an information about features – find a code of a regional town
10. Turn on an orthophoto map
11. Find a legend for the layer of municipalities with extended competence
12. Turn on an overview map (a small map placed at the bottom) and use it to center a big map to the regional town at a scale approx. 1 : 500 000
13. Display names of streets in the regional town
14. Use a search tool to find regional town in the map

NGOMSL model is proposed in accordance with user testing scenario. Tasks are transformed into particular activities.

Task 1

1.1 Type search keywords into Google field to start searching for starting page of the application

1.2 Enter the main menu of the application

1.3 Document tasks fulfilment

Task 2

2.1 Find a link to open a map of administrative division of the region

2.2 Enter of the GIS application, namely map of administrative division, by means of the found link

2.3 Document tasks fulfilment

Task 3

3.1 Find a scale of the map

3.2 Set a scale of the map to 1 : 20 000. If there is no scale, set 1 km at scalebar

3.3 Document tasks fulfilment

Task 4

4.1 Find a toolbar containing tools to control the map (pan, zoom, refresh functions)

4.2 Find a tool “Undo/Back”

4.3 Document tasks fulfilment

Task 5

5.1 Find a list of available layers

5.2 Turn on the layer containing municipalities with extended competence

5.3 Turn off all other layers

5.4 Document tasks fulfilment

Task 6

6.1 Pan the map to focus it on any of municipalities with extended competence

6.2 Set a scale of the map to 1 : 50 000. If there is no scale, set 2 km at scalebar

6.3 Display name of the above focused municipality with extended competence

6.4 Document tasks fulfilment

Task 7

7.1 Find tools for zooming in and out and tools for changing a size of the map

7.2 Use one of the tools to display all municipalities with extended competence in the map

7.3 Document tasks fulfilment

Task 8

8.1 Find a tool for distance measurement

8.2 Measure distance between two chosen municipalities with extended competence

8.3 Document tasks fulfilment

Task 9

9.1 Find a tool for obtaining descriptive information about features

9.2 Find a code of the regional town

9.3 Document tasks fulfilment

Task 10

10.1 Find a tool for changing background maps

10.2 Switch a background map to orthophoto map

10.3 Document tasks fulfilment

Task 11

11.1 Find a legend for all layers

11.2 Find a symbol used for municipalities with extended competence

11.3 Document tasks fulfilment

Task 12

12.1 Find a smaller map on the screen – an overview map

12.2 Set a scale of the map to 1 : 50 000. If there is no scale, set 2 km at scalebar

12.3 Use the overview map to display name of the regional town

12.4 Document tasks fulfilment

Task 13

13.1 Find a tool to display street names

13.2 Find name of a street in map window

13.3 Document tasks fulfilment

Task 14

14.1 Find a suitable tool to search for names of municipalities

14.2 Find and display regional town in the map by means of this tool

14.3 Document tasks fulfilment

Total performance time is calculated as a sum of: (time of NGOMSL tasks * 0.1 s), operators, mental operators, and response time of system. For example, an average time for operator 'find' is 18.6 s.

The last step of preparation of both usability user testing scenario and NGOMSL model is pilot testing. Results concerning scenario for user testing are mention above. Pilot testing is used as a source of one more important information for the next step: a maximum time available for users to try to solve tasks. After reaching deadline, the task is marked as not fulfilled. The deadline is set as tree-times longer time than time necessary for pilot testing but no longer than 300 s (5 min) to keep reasonable times. E.g. for distance measurements, the pilot testing time was 47 s, so deadline is set to 141 s. [4]

F. Evaluation Planning

Three Web-based GIS applications represent subjects of evaluation. Two methods are chosen for the evaluation so evaluation must be planned in a way, which prevents learnability effect. The evaluation plan is described in the Table 1

TABLE I. PLAN FOR USABILITY EVALUATION

	Participants	Order of Evaluated Applications		
		Pardubicky	Moravsko-slezsky	Stredoces-ky
User Test.	Participant 1 and 2	1	2	3
	Participant 3 and 4	3	1	2
	Participant 5 and 6	2	3	1
NGOMSL model	Participant 8 and 9	1	2	3
	Participant 7 and 11	3	1	2
	Participant 10 and 12	2	3	1

G. Evaluation Itself

Usability user testing is done in couples. A participant fulfils tasks, an inquirer measures times necessary to finish tasks. In the case of exceeded time, he stops participant. Participant makes printscreens and enters answers and times into Excel sheet (see Fig. 2.) Next, participant fulfils subjective evaluation of all application in Excel. Scale from 1 (the best) to 5 (the worst – fully unsatisfied) is used. As the last step, participant is asked to compare importance of evaluated functions (by pairwise comparison).

Similar approach is used for NGOMSL model based evaluation. All tasks and questionnaires are provided in Excel.

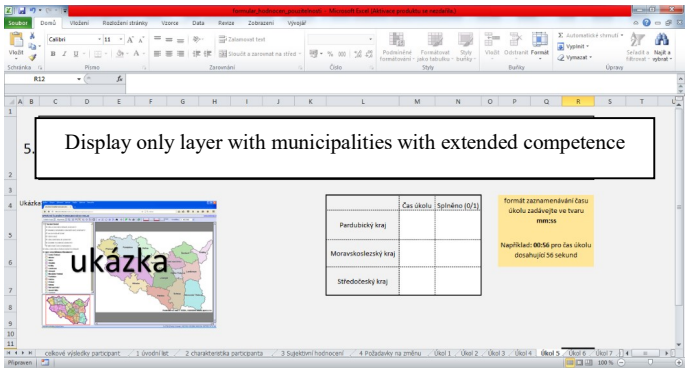

Figure 2. Environment for Usability User Testing (source: [4])

H. Results Interpretation

1) Usability User Testing

At first, times necessary to finish particular tasks must be summarized and an average is calculated. An average time necessary to evaluate one application is 11 min 36 s in this case study. The shortest time was necessary to finish task 1 (27.9 s), the longest time was necessary to finish task 13 (93.5 s)

Next, a multi-criteria approach is used to set weights for all particular criteria to allow to calculate a utility at the end. Evaluation obtained from participants by pairwise comparison is used in this step. Weight of the group of subjective criteria is 0.5, weight of the group of performance criteria is 0.5 as well. Then, a utility per user per application is calculated and finally, an average utility per application is calculated. The final utility is as follows: Moravskoslezsky – 0.33 (see Fig. 3); Pardubicky – 0.19 (see Fig. 4); Stredocesky – 0.18 (see Fig. 5).

2) NGOMSL Model

Time necessary for evaluation is slightly shorter than in case of usability user evaluation. Time calculated in advance is 9 min 1 s. In reality, the following times were necessary: 7 m 31 (Moravskoslezsky), 9 min 22 s (Stredocesky), 9 min 28 s (Pardubicky) in comparison with above mentioned 11 min. [4]

I. Summary

Both methods provided very similar results concerning necessary times and identified problems in usability. Distance measurements (66.7 s in user testing and 62 s in NGOMSL), search tools (64.8 s in user testing and 30.8 in NGOMSL) and

displaying names of streets (93.5 s in user testing and 76 s in NGOMSL) can be given as the most serious problems in usability [4]. In fact, they belonged to the identified problems in usability during previous study as well [9]. The highest number of problems in usability was found in the case of Pardubicky region application (see Fig. 4), which has not been change since the previous study. Its most serious problem in usability is utilization of Java applet, which in fact makes utilization of this application impossible because it requires users to allow dangerous plugins in web-browser. Setting a map scale to approx. 1 : 200 000 was the easiest task (29.4 s in user testing and 16 s in NGOMSL) [4].

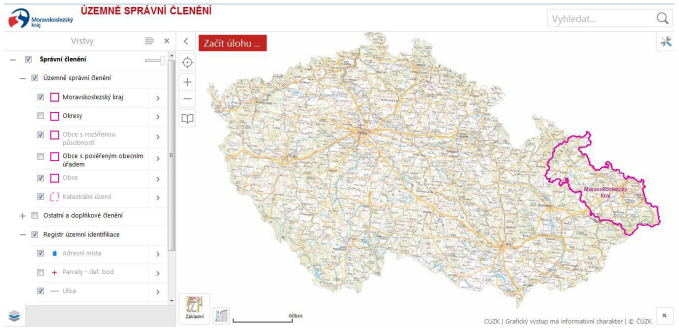

Figure 3. Web-Based Application of Moravskoslezsky region

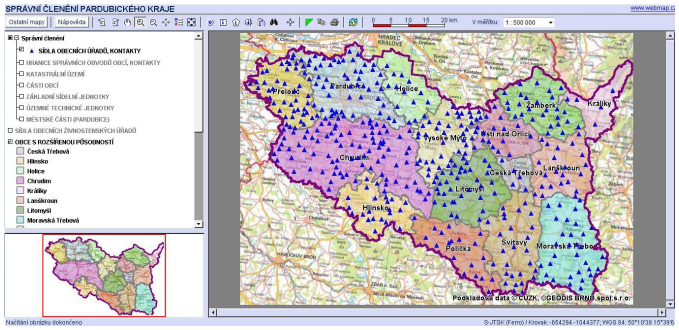

Figure 4. Web-Based Application of Pardubicky region

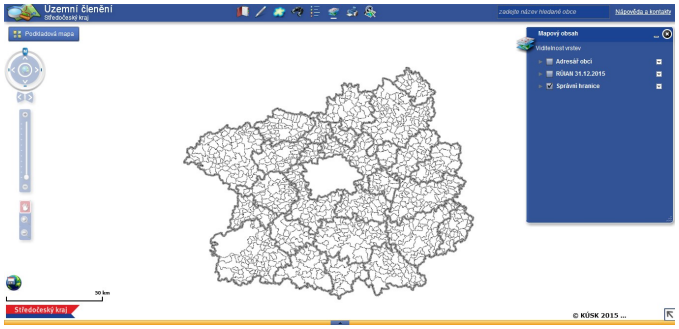

Figure 5. Web-Based Application of Strdocesky region

IV. CONCLUSION

Usability evaluation can significantly help designers to design a high-quality user interfaces to support users and their work. It is very important especially in the case of Web-based GIS because they are designed for end-users without GIS knowledge as a part of e-Government service. It means that application must prevent users to make mistakes. Usability user testing includes representatives of users which is very important on one side but it is very time and costs demanding on the other side. Combination of more methods can bring results in a more efficient way.

The case study shows that NGOMSL model can be successfully used for usability evaluation. It is able to provide similar results in a shorter time in comparison with a traditional usability user testing.

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