Methods of usability evaluation of web-based geographic information systems

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***Abstract*—**Spatially influenced decision-making plays an important role in human lives. Suitable software tools can significantly support process of decision-making. Desktop geographic information systems (GIS) applications have been used by professional for many years, but they are not suitable for end users. Special kind of GIS applications, usually called Web-based GIS, is focused on end users, i.e. on casually working people who may have only a very limited knowledge of GIS, if any. Their computer literacy can be very low as well. Design of Web-based GIS should respect this reality so applications should be proposed with a strong focus on their usability. This article deals with suitable methods of usability testing of Web-based GIS. Several usability problems identified during previously done usability testing are described. Recommendations, how to prevent usability problems, are provided in the end of the article.

***Keywords*—**Spatial decision making, Web-based GIS, Usability, Heuristics, Heuristic evaluation.

I. Introduction

Mankind uses spatial information during its whole life. Nowadays, modern information and communication technologies are used to collect, store, analyze, update, transmit and visualize spatial data/information. Software, which allows users to utilize spatial data and run their analyses, is called geographic information system (GIS). Today, many various kinds of GIS applications exist. They significantly vary in available functions. Some of them are commercial solutions; some of them are open source solutions. Rich desktop applications are mostly intended for GIS professionals or other specialists who need a fully functioning solution. Desktop solutions were very popular in the 1990s. Later on, several different GIS software types were created, e.g. server solutions, mobile solutions, Internet solutions. There is a very important advantage of server solutions – they allow concurrent processing of users' requests [1]. Decreased costs per a user, improved data protection, easier software and data maintenance, and support of a team work can be stated as other advantages. Server solutions are today able to provide many sophisticated applications like desktop solutions, i.e. they can allow data editing, they can provide cartographic functions, complex spatial analyses, etc. The problem is, that the above listed functions usually require high level of user's skills and knowledge, namely in the GIS field.

All available functions are usually not required and used by the majority of GIS users. The most often required functions are only the following functions:

- Features searching and identification (i.e. data queries)
- Data visualisation – it mainly means zooming, panning and possibly turning data layers on and off
- Saving and/or printing results (e.g. URL saving, printing output maps).

Access to relevant data is a very important issue for users because without data there is no need for application. Today, data come from various sources, especially for complex problems, e.g. urban planning. Data exchange system, which includes metadata, can significantly help. [2]

Security and user's identification and authorisation are very important issues as well because sensitive data can be provided by applications. On the other side, various identification and authorisation methods mean various costs and various level of security. [3]

End users use applications only casually so they may not remember how to use it. Thus, end users need a simple, user-friendly environment. [1], [4]

Web browser can easily meet the above stated requirement so it is today used as a general multi-purpose client application. It provides "well-known" user environment because people are used to use Internet so they know how to work with a web browser. Furthermore, contemporary Web applications can provide adaptive user interface using many various technologies [5]. Because of many positives, e.g. low costs per user, Web-based GIS applications (in general Internet applications) have become the most wide-spread GIS solutions [1]. Next advantage of Web-based GIS applications is their standardization and ability to use web services technology to cascade (mash-up) services into one application [6]. Architecture of Web-based GIS applications is usually based on the n-tier client/server architecture. The following layers should be recognized:

- Presentation layer – user interface
- Web server – communication between Web browser and application

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- Application layer – application logic, i.e. the part processing data to answer users' requests
- Data layer – data storage and access.

The article is focused on a user interface quality, i.e. on the presentation layer. The article has two main aims. The first one is to discuss advantages and disadvantages of several usability evaluation methods and to propose a suitable way for usability evaluation of Web-based GIS applications. The second aim is to describe the most serious usability problems which were identified during realized case studies.

II. Usability as a Quality Characteristics of Information Systems

Easily accessible services in a user-friendly environment should by provided by information systems to their users. Several standards have been developed to evaluate overall quality of an information system. The quality characteristic of software which deals with a user's view on an application is called usability.

A. Usability

Usability as a quality characteristics is defined by many authors and several ISO standards, e.g. ISO/IEC 9126 and ISO/IEC 9241-11 [8] - [10]. According to the available definitions usability can be understood as an ability of a system to fulfil all explicit (expressed) requirements and implicit user's needs in a given context of use. In more detailed point of view usability means that an application is usefulness, efficient, effective, learnable, accessible, and satisfying [10]. Usability attributes cover [11]:

- Objective measurement of user performance, e.g. efficiency of user's work
- Subjective user view, e.g. attractiveness of a system.

B. Usability Evaluation Methods

Many various methods of usability evaluation and testing have been developed. Usability evaluation methods belong to classical experimental methods. Available evaluation methods can be classified according to many different criteria [4], [7], [9] - [12]:

- Empirical usability testing, usability inspection, or inquiry
- Necessity of an application existence, more precisely availability of user interface (application has already been programmed or it is just planned)
- Current stage of software development life cycle
- Inclusion of real users or their representatives into usability evaluation
- Testing in an artificial (experimental) environment or observation of real users in their real environment
- Level of automation of an usability evaluation
- Kind of obtained results, i.e. quantitative or qualitative results can be obtained.

Many of the above listed criteria are highly connected to each other, e.g. it is quite difficult to involve real users when there is no user interface available.

Detailed description of existing usability evaluation methods is available in many books and articles, e.g. [4] - [13], so it is not provided here.

Usability user testing, heuristic evaluation, card sorting, and inquiry (questionnaire) were used as usability evaluation methods for the purpose of this study.

All used methods are briefly described in the following chapters.

III. Case Study 1

Web-based GIS applications were selected as a target of our case study. More precisely, all 14 applications of the Czech regional authorities were selected for evaluation because they are focused on the same type of users and they are run by the same type of public administration authority.

Regional level is the second top level of public administration in the Czech Republic. Regions and regional authorities (or county councils) were established by the Act No. 129/2000 Coll. According to this act, regional authorities are self-governing authorities which are responsible for regional development. In the Czech Republic, there are 14 regions (including the capital – city of Prague). According to several legal regulations, public administration authorities have to publish information to the public. Information must be accessible remotely, i.e. information is published on Internet. Authorities are not required to use Web-based GIS application but they have to publish spatial information so Web-based GIS applications can help them to do it. Target group of users of the applications is the public, i.e. people without any GIS knowledge and skills. Additionally, low level of a computer literacy can be expected as well. Their equipment (hardware, software, and Internet connection) can differ so it cannot be defined in general. Both skills and technical environment cannot be influenced; it must be respected by design of an application.

Evaluated Web-based GIS applications used different software: ArcIMS, ArcGIS Server (both ESRI), T-MapServer (T-MAPY, Czech Rep.), Map Server (based on UMN MapServer, Help Service – Remote Sensing, Czech Rep.), Web Map (Hydrosoft, Czech Rep.), and UMN MapServer (design by Fun Maps, Czech Rep.).

The first part of this case study was published in [7]. In the previous part of this study, usability user testing was used to evaluate usability of selected applications. In this part heuristic evaluation was used to identify usability problems and possibly to allow us to compare obtained results although the whole study was run as a qualitative research. Unfortunately, three applications were changed during the whole process of usability evaluation. It makes comparison of obtained results even more complicated.

A. Aim and purpose of the evaluation

The study is focused on Web-based GIS applications which are intended for casually working end users without any GIS skills. As it was mentioned above, this is a part of an on-going study. Both parts have the same aims and purpose of usability

evaluation [7]:

- Identification of serious usability problems of the evaluated applications,
- Only qualitative results are expected.

B. Used Method – Heuristic evaluation

Heuristic evaluation can be used during the whole software development life cycle except for requirement analysis. This method belongs to the usability inspection methods with lower costs of evaluation. Heuristics is a recognized usability principle. Usability of a system is evaluated simply – compliance of the system with the heuristics is tested. Evaluation is done by several evaluators. Each evaluator does his work alone without any special equipment and environment. Their results are then united into one final evaluation. One of the most important disadvantages of this method is detection of many not so important usability problems (result can be a very long list of usability problems). [9], [11]

The first set of heuristics for Web-based GIS applications evaluation was proposed by the authors in [4]. That set contained 138 heuristics, divided into several thematic categories. For the purpose of this study the set was updated and abridged. Obsolete heuristics and heuristics dealing with functionality or data quality were excluded, some heuristics were rephrased and two heuristics were added. The resulting list contained only 92 heuristics. Finally, all heuristics were divided into five thematic groups to make possible future data processing easier [14]:

- Cartographic environment,
- User interface – its clarity and understandability,
- Accessibility and ease of use of available functions,
- General computer environment,
- Errors and their handling.

The whole set of heuristics is provided in the Appendix.

The next step was to determine weight of each heuristics. In this case, 5 evaluators took part in this step. The evaluators had different level of general GIS skills, Web-based GIS applications authoring skills and general Web pages authoring skills [14]:

- Evaluator 1 – higher level of general GIS skills, and Web-based GIS applications authoring skills; basic general Web pages authoring skills,
- Evaluator 2 – expert in GIS, and Web-based GIS applications authoring skills, basic general Web pages authoring skills,
- Evaluator 3 – higher level of all general GIS skills, Web-based GIS applications authoring skills, and general Web pages authoring skills,
- Evaluator 4 – basic level of general GIS skills, and Web-based GIS applications authoring skills, expert in general Web pages authoring,
- Evaluator 5 – higher level of general GIS skills, and Web-based GIS applications authoring skills; basic level of general Web pages authoring skills.

Resulting weight of each heuristics was calculated using (1) where v_j refers to the resulting weight, c_j refers to particular weights set by each evaluator. Each evaluator could use 5 point scale (0 – 4) to express level of importance of each heuristics.

$$v_j = \frac{c_j}{\sum_{j=1}^{n} c_j} \tag{1}$$

Because of the number of evaluators, the resulting weight could fell into interval <0;20>. Importance of a usability problem was determined using 5 levels of problems importance [9] as follows [14]:

- Interval <0; 3,2) → {0; 1; 2; 3} means level 0, i.e. no usability problem,
- Interval <3,2; 7,4) → {4; 5; 6; 7} means level 1, i.e. cosmetic usability problem,
- Interval <7,4; 11,6) → {8; 9; 10; 11} means level 2, i.e. minor usability problem,
- Interval <11,6; 15,8) → {12; 13; 14; 15} means level 3, i.e. major usability problem,
- Interval <15,8; 20> → {16; 17; 18; 19; 20} means level 4, i.e. the most serious usability problem.

Resulting level of importance of each heuristics is provided in the Appendix.

C. Evaluators and their Equipment

One person is not able to find all usability problems so higher number of evaluators is recommended [9].

In this case, 2 evaluators took part in the evaluation process. The evaluators had a little bit different level of general GIS skills, Web-based GIS applications authoring skills and general Web pages authoring skills. One evaluator was more experienced in all fields. Evaluators had different equipment to run evaluation in different conditions [14]:

Evaluator 1:

- Notebook: Asus F5RL
- CPU: Intel Core 2 Duo T5850 2,16 GHz
- Memory: 3072 MB,
- External screen: 17”, resolution 1600x1200, colour depth: 32 bit
- Operating system: Windows Vista Home Premium SP1
- Web browser: Internet Explorer 8, version 8.0.6001.18813; Firefox version 3.5.2; and Opera version 9.64
- Available additional software: Java™ Platform Standard Edition 6 version 1.6.0
- Internet connection speed: 6 Mbps.

Evaluator 2:

- PC: Dell OptiPlex 755
- CPU: Intel Core 2 Duo E6750 2,66 GHz
- Memory: 2048 MB
- Screen: 19’’, resolution 1024x768, colour depth: 32 b
- Operating system: Windows XP Professional SP3

- Web browsers: Internet Explorer 8, version 8.0.6001.18702; Firefox version 3.5.2; and Opera version 9.64
- Available additional software: Java™ Platform Standard Edition 6 version 1.6.0
- Internet connection speed: 100 Mbps.

Java™ Platform was necessary, several applications required it.

D. Process of Heuristic Evaluation

The heuristic evaluation itself took in total 48 hours to both evaluators. At first, it was necessary to go through all evaluated applications just to familiarize evaluator with the applications and to verify proposed heuristics. Then, 1.2 hours was an average time for one evaluator to evaluate one Web-based GIS application. Results of both evaluators were aggregated into one final evaluation. It was enough when one evaluator found a problem. [14]

E. Obtained Results

At first, penalty points were calculated. Calculation was done using weights set in a previous step. Obtained results are shown in the Fig. 1 and Fig. 2. Overall results for all regions are shown in the Fig. 1. The less penalty points, the better is application – with less usability problems. Regions are ordered according to the results. Fig. 2 keeps the same order of the regions. It shows number of occurrence of the most serious usability problems. It can be observed that better applications had less serious usability problems than worse applications.

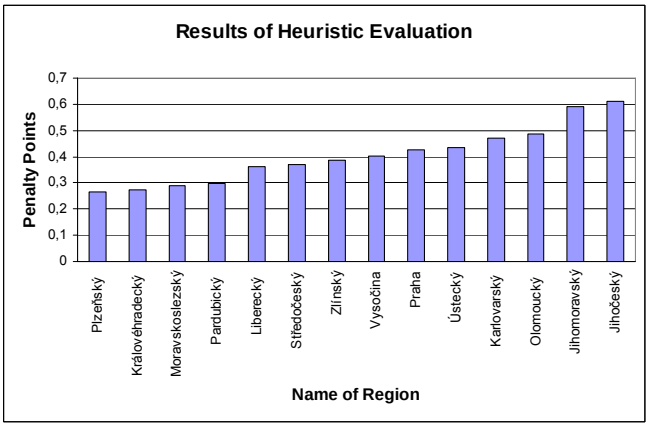

Fig. 1 - Results of heuristic evaluation (source: authors, based on data from [14])

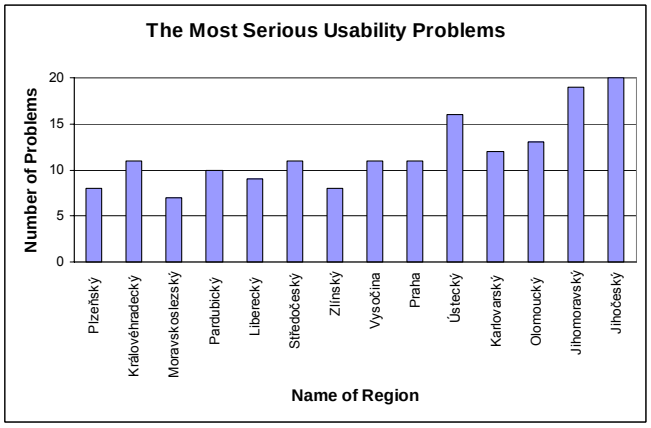

Fig. 2 - Results of heuristic evaluation – number of occurrence of the most serious usability problems (source: authors, based on data from [14])

The Pearson's correlation coefficient *r* was calculated in MS Excel using function PEARSON [15] to identify dependency of number of the most serious usability problems on the total number of penalty points – see eq. (2). The resulting value r = 0.86 says that the level of dependency is quite high. Pearson's correlation coefficient equation:

$$r = \frac{\sum_{i=1}^{n}\left(X_i - \overline{X}\right)\left(Y_i - \overline{Y}\right)}{\sqrt{\sum_{i=1}^{n}\left(X_i - \overline{X}\right)^2}\sqrt{\sum_{i=1}^{n}\left(Y_i - \overline{Y}\right)^2}} \qquad (2)$$

where *r* denotes Pearson's correlation coefficient; X_i, Y_i denote values; $\overline{X}$, $\overline{Y}$ denote an average.

Although testing was run as a qualitative research, it can be stated, that obtained results are quite similar to the results obtained by the usability user testing. The same applications were found as usable and the same applications were found as problematic ones [7].

F. Identified Problems and their Possible Solutions

Following most serious usability problems were most frequently identified (number of the heuristics from the list given in the Appendix and number of occurrences are given in the brackets) [14]:

1. *Utilization of pop-up windows* (heuristics No. 83, 12 occurrences)

Web application can be modified to use a regular solution using extra HTML tag (usually tag DIV) which is styled via CSS as an extra layer on the top of the rest of HTML page. This extra tag simulates and looks like a window which is on the top. Content of this "window" can be anything – warning message, image, extra map view, frame with content of another web page, etc.

Example of suitable source code in HTML, CSS and JavaScript follows:

HTML:

```
<div id="message">Text of the message</div>
```

CSS:

```
#message {
   z-index: 2;
   position: absolute; /* or relative or fixed */
   top: 40%;
   left: 45%;
   width: 10%;
   display: none;
}
```

JavaScript:

to show: document.getElementById('message').style.display = "block";

to hide: document.getElementById('message').style.display = "none";

to change message (or insert any HTML content): document.getElementById('message').innerHTML = "text of the new message";

2. *Utilization of not enough expressive* icons (heuristics No. 17, 11 occurrences)

At first, usually used icons should used – in their typical way. Next, tooltip help can significantly improve usability. A graphic designer with usability experiences should improve the icon set. Another usability testing can be performed to verify an improvement.

3. *Difficult clearing of selection results* (heuristics No. 49, 11 occurrences)

An extra function represented by an appropriate icon for clearing selection should be inserted.

4. *Impossibility to save URL of the created map* including precise location, scale, etc. (heuristics No. 57, 11 occurrences)

Method GET should be preferably used instead of POST because it transfers parameters in URL so it can be saved. Next possibility is JavaScript. Today it allows to change URL without reloading a Web page. So parameters (as position, zoom, layers etc.) can be stored in URL and application can be modified to get these parameters.

Classic solution in JavaScript via Value accessible with JavaScript construction document.location.href (URL itself) can be read and changed to store needed parameters as location, x and y coordinates, zoom etc in GET parameters in URL. Example:

http://www.mapy.cz/?x=135524352&y=135829504&z=9

Each change of this value forces reloading the page. Therefore this solution is not quite useful for web application like online maps – every movement (panning) on the map forces reload of the whole web page.

The *better solution* uses a little different approach to the parameters transmission. If application uses # char (part of URL for document anchor) like in this example:

http://www.mapy.cz/#x=135524352@y=135829504@z=9

Anchor part of URL is accessible in JavaScript via document.location.hash and change of this value does not force reload of web page.

Particular parameters are separated with char @. On client side, application translates the whole part of URL after # char to the separate parameters, in our example to x, y coordinates and zoom level.

This kind of URL is transferable for example via e-mail and recipient will have the same map position and look as sender.

5. *Error reports do not provide any information about possible causes of a mistake* (heuristics No. 90, 10 occurrences)

Error reports should be rewritten to be more specific. This change is more difficult than other improvements because it need changes in application core (source code).

G. Raised Problems Connected to Used Usability Evaluation Methods

The firstly used methods, heuristic evaluation and usability user testing (described in this article, in [4] and [7]), were quite slow and demanding methods. Especially usability user testing requires a special testing room, special equipment and a huge amount of time. On the other side, heuristic evaluation is faster; it does not require a special testing room and other special equipment. But it does not include any representatives of users so this point of view is missing.

IV. Case Study 2

This case study was inspired by the idea that more rounds of testing, even with fewer users, can bring better results than one testing with a higher number of users [16]. Within this case study a specially designed Web-based GIS application was designed by the authors and then evaluated – see Fig. 3. ArcGIS Server 9.3 was used as a software platform.

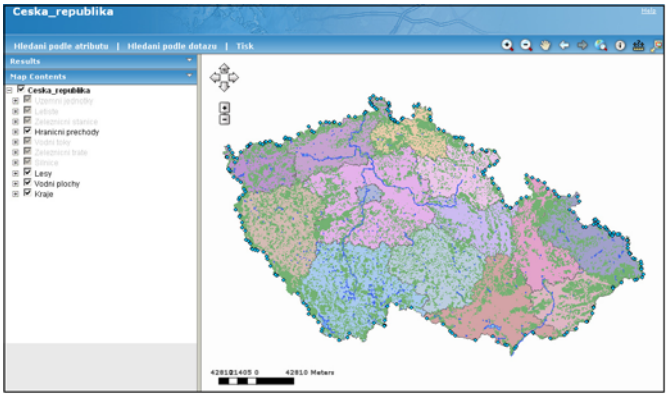

Fig. 3 – User interface of evaluated application

A. Aim and purpose of the evaluation

The second case study had two main aims:

- To identify user preferences and serious usability problems by evaluation of a chosen Web-based GIS application interface
- To propose and verify a usability evaluation methodology suitable for Web-based GIS application (targeted at end-users).

The evaluation was focused on the following functional and

cartographic elements of the application [17]:

- Zooming (changing scale)
- Panning
- Printing
- Searching
- Data layers controlling
- An overview map utilization
- Scale/scale bar of the map
- Help
- Distance measurement
- Map title.

B. Proposed Methodology

The proposed methodology should lead to decreasing time necessary for evaluation of applications and results processing. It should decrease all necessary resources and costs too. At least a partial involvement of users was required. Utilization of several different methods was chosen as a suitable approach. The new methodology consists of the following usability evaluation methods [17]:

- Closed card sorting,
- Heuristic evaluation,
- Questionnaire.

Closed card sorting and heuristic evaluation are understood as qualitative methods, questionnaire can be used as a method for quantitative data collection – as it was in the case of this study. So the mixed research method was used.

Closed card sorting is a very cheap, fast and understandable method which allows to involve real users. Card sorting allows to find opinion of people about user interface and their preferences. It can be used during all staged of software development life cycle. [18]

Each card represents one of the evaluated functional and cartographic elements (listed in the text above). Groups for card sorting are predefined (important and unimportant) and cards in each group must be ordered according to their importance. Users do not fulfill any tasks, they just observe evaluated application.

Heuristic evaluation – very cheap method which does not need real users or their representatives; shortening the list of the heuristics to 36 rules significantly shorten time necessary for evaluation. Shortening was possible thanks to utilization two additional usability evaluation methods. Heuristics used in this case study come mostly from the parts I, II, and III of the set proposed in the Appendix. They are straightly focused on user interface and interaction of user with the interface. They deal only with above listed functional elements to decrease time necessary for evaluation. Used set of heuristics [17]:

1. Is it possible to measure distance?
2. Is it possible to set measurements units?
3. Is graphical scale bar available?
4. Is numeric scale available?
5. Is it possible to set scale of the map precisely according to user's needs?
6. Is tooltip help available for icons?
7. Is a link to help available?
8. Is it easy to enter help and go back to the application?
9. Is it possible to pan map by arrows in an active margin of a map?
10. Is it possible to pan map by a mouse?
11. Is it possible to pan map by a keyboard?
12. Is it possible to turn off an overview map?
13. Is an overview map available?
14. Is a printing tool available?
15. Is it possible to set advanced print settings?
16. Is print preview available?
17. Is the map on the screen the same as the printed map?
18. Is it possible to choose quality of map (primarily for printing)?
19. Are data layers ordered according to their importance and relevance to the map topics?
20. Is legend for data layers available?
21. Is it possible to turn data layers on and off?
22. Is description of data layers available?
23. Is it possible to change vertical order of data layers?
24. Is it possible to turn map filed on and off?
25. Is it possible to set transparency of selected data layer or symbol?
26. Is it possible to search according to several criteria?
27. Are all available data layers searched automatically?
28. Are searching results linked back to the map?
29. Is searching case-insensitive?
30. Does searching provide options, e.g. drop-down menu?
31. Is it possible to search within drop-down menu by pressing the first letter of a searched word?
32. Is it possible to zoom map in by double-click?
33. Is it possible to zoom map in by an interactive selection of a region in map by mouse?
34. Is it possible to zoom map in by mouse wheel?
35. Is it possible to zoom map in by keyboard?
36. Is a map title provided?

Questionnaire – still quite fast method which again allows to involve real users. At first, a questionnaire with simple tasks was proposed. Then, a set of more complex (and complicated) tasks was proposed. Users had to fulfill all given tasks at first, then they answered a questionnaire.

Used set of simple tasks [17]:

1. What is a title of the map, you are working with?
2. Where is a scale/scale bar?
3. Where is icon for printing?
4. Where is help?
5. What is ZIP code of municipality Dolni Slivno?
6. Which city is situated to the west from Cerhenice?
7. What is the distance between Klatovy and Pelhrimov?
8. What is area of lake Rozkos?
9. Which colour is used to border area of interest in the overview map?

Results of the above described methods are not comparable

but by means of the methods it is possible to get a comprehensive overview of user's preferences, needs and usability problems of evaluated application.

The proposed methodology does not require any specially equipped testing room. It is understood as the next important advantage of the methodology.

C. Evaluation

Evaluation of the application was done according to proposed methodology.

Closed card sorting: users did not use the application to solve any tasks but they can look at it. Users were required to classify cards into two pre-defined groups: important and unimportant. In total, 21 users took part in the evaluation. They did the evaluation at the same time, in the same room and they needed one hour. Additionally, three hours were necessary for results processing. [17]

Heuristic evaluation: five experts took part in heuristic evaluation. They set weights for all heuristics to express importance of each heuristics (and consequently each usability problem). The same scale as in the case study 1 was used.

Questionnaire: as far as it was understood as a quantitative method, 91 users took part in this evaluation. Evaluators were university students from various school years, without GIS skills. At first, they had to fulfill given tasks, then they answered questionnaire. In average, they needed 14 minutes to fulfill the tasks. It took 7 hours to process results.

D. Obtained Results

Description of collected results follows.

Closed card sorting: resulting order of functional elements according to their importance as determined by users [17]:

1. Searching
2. Panning
3. Zooming (changing scale)
4. Distance measurement
5. Scale/scale bar of the map
6. Data layers controlling
7. Printing
8. Map title
9. An overview map utilization
10. Help.

Heuristic evaluation: according to experts, importance of functional elements is as follows [17]:

1. Help
2. Zooming (changing scale)
3. Searching
4. Data layers controlling
5. Scale/scale bar of the map
6. Panning
7. Printing
8. An overview map utilization
9. Distance measurement
10. Map title

Questionnaire: an average percentage of simple tasks finishing was 76 % in average time 13 min 51 s. The easiest tasks were focused on map title (No. 1), printing (No. 3) and searching (No. 5). The most difficult was task No. 6 which was more complex and required ability to control data layers. An overview map was next complicated task (No. 9) [17]. Level of completion of all tasks is shown in Fig. 4.

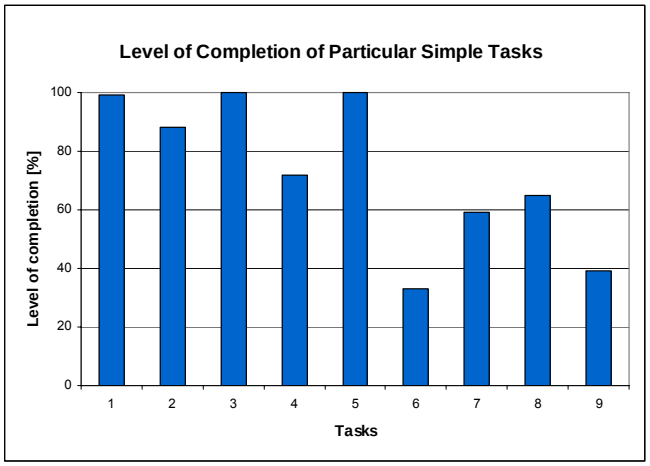

Fig. 4 – Level of completion of tasks (source: authors)

E. Discussion

The first experience with the proposed methodology is positive. Evaluation methods were less demanding on participants and less costly than the method used in [7]. On the other side, representatives of real users were still involved. Card sorting is simple, fast and understandable method. Users can easily express then preferences. Heuristic evaluation involves only experts. It demands a well-prepared and verified set of heuristics. Questionnaire with simple tasks was better choice than questionnaire with complex tasks. Complex tasks were closer to usability user testing. The problem was, that user was not able to skip an unknown step so he could not finish task even in the moment when he would be able to do it. Obtained results showed that it is very important to involve both real users (or their representatives) and experts.

V. Conclusion

Each Web page should be intuitive, understandable and self-explaining so users can use it without thinking [16]. This is valid for Web-based GIS application too because they provide access to special kind of data (spatial information), otherwise they are Web pages.

Usability evaluation should have become a part of a software development life cycle because it can increase software quality and its capability to satisfy users and their needs. There are several issues which should be taken into account. Testing should be an iterative process to increase number of identified problems for reasonable costs. Costs of the testing can significantly increase resulting price of the software – this can be given as an example of a significant problem connected with usability evaluation.

Usability evaluation method proposed in the article will be used in the future for next improvements of Web-based GIS application user interface assessed in the case study 2. Iterative evaluation is planned together with utilization of other methods to verify, that proposed methodology brings higher benefits with lower costs.

Elimination of identified problems is usually not very difficult from the technical point of view, but it can be time demanding, e.g. when author of source code is not available and there is no documentation available too.

APPENDIX

TABLE I
PROPOSED AND USED SET OF HEURISTICS – CASE STUDY 1 [14]

No	Heuristics	Importance of Usability Problem
I	**Cartographic environment**	
1	Is a graphic scale bar available?	4
2	Is a number scale available?	2
3	Is it possible to se the scale exactly according to user's needs?	3
4	Are there set suitable limit scales for data layers?	3
5	Are data layers ordered according to their importance considering map topic?	2
6	Is legend available?	4
7	Is it possible to choose layers which will be visible?	4
8	Is it possible to set an automatic map reload when map is changed?	2
9	Is an overview map available?	3
10	Is it possible to find the date of data sets origin?	2
11	Is description of data sets available?	3
II	**User interface – its clarity and understandability**	
12	Are maps divided according to their topics?	3
13	Are elements of pages placed suitably?	3
14	Is the map field the largest part of the application?	4
15	Are icons ordered according to the importance of their function?	2
16	Are icons divided into thematic groups?	2
17	Are icons enough expressive according to their function?	4
18	Is it possible to distinguish selected icon from all other icons?	3
19	Do icons have a tooltip help?	4
20	Are labels of fields understandable, brief, proper and enough expressive?	4
21	Are labels in Czech?	4
22	Are labels grammatically correct?	3
23	Are used term commonly used and known?	4
24	Are important elements of a page highlighted?	3
25	Is there an adequate colour contrast between background and font?	4
26	Does the whole application used only one colour scheme?	3
27	Do all maps of the Web site use the same user interface?	4
28	Is the font size adequate so texts are readable?	4
29	Is it possible to resize font by means of standard functions of Web browser?	3
30	Is there enough free space around text fields so text is readable and clearly arranged?	2
31	Does each page contain "title" or "head" to express its content?	2
32	Is the page title placed close to the top left corner?	2
33	Is information from Web browser status bar places somewhere else in the page?	2
34	Is there available any feature which informs about the state of page loading?	4
35	Are used clear abbreviations?	3
III	**Accessibility and ease of use of available functions**	
36	Is there a button allowing to go back to the previous extent of the map?	3
37	Is there a button allowing to go forward to the previous extent of the map?	3
38	Is it possible to pan map by mouse?	4
39	Is it possible to pan map by keyboard?	3
40	Is it possible to pan map by arrows in an active margin of a map?	3
41	Is it possible to zoom map in by double-click?	3
42	Is it possible to zoom map in by interactive selection of a region in map by mouse?	4
43	Is it possible to choose a size of a map field ("viewport")?	2
44	Is there a tool which allows to display full extent of a map?	4
45	Is there a tool which allows to identify a selected feature in the map?	4
46	Is it possible to measure distance directly?	3
47	Is it possible to measure distance along line features?	3
48	Is it possible to measure area of a polygon?	3
49	Is it easy to clear selection?	4
50	Is it possible to set up units?	3
51	Does application contain a tool for printing maps?	4
52	Is it possible to set additional settings for print?	3
53	Is preview before print available?	3
54	Is a map on the screen the same as the printed one?	4
55	Is it possible to choose a quality of a map (namely for printing)?	3
56	Is it possible to save resulting map as a picture?	4
57	Is it possible to store URL of a map (including location, scale, etc.)?	4
58	Is cursor automatically placed in the most often used field when user enters Web page or a dialog window?	1
59	Is link to help available?	4
60	Is it easy to enter help and return back to the application?	3
61	Is easy to input queries?	4
62	Is it possible to search according to several criteria?	3
63	Are all data layers searched automatically?	3
64	Are search results linked back to the map?	4
65	Is it possible to centre map so the selected feature is in the centre?	3

No	Heuristics	Importance of Usability Problem
66	Is search case-insensitive?	4
67	Is autocomplete function available when query is entered?	2
68	Does search provide alternatives, e.g. drop-down menu?	2
69	Is it possible to search within drop-down menu by pressing the first letter of a searched word?	2
70	Does the page offer other maps available in the Web site?	3
71	Is it possible to use common keyboard shortcuts (e.g. Ctrl + C, Ctrl + V)?	4
72	Can user do more than just react to systems (i.e. can user initiate actions)?	3
IV	**General computer environment**	
73	No plug-in is necessary?	4
74	No other additional software is necessary (e.g. Java)?	4
75	If a plug-in or another software is necessary, is a link for download available?	4
76	Does application work correctly in MS Internet Explorer?	4
77	Does application work correctly in Firefox?	4
78	Does application work correctly in Opera?	4
79	Is application uncluttered with screen resolution 800x600 and maximized window?	3
80	Is application uncluttered with screen resolution 1024x768 and maximized window?	4
81	Is application uncluttered with screen resolution 1280x1024 and maximized window?	4
82	No HTML frames are used?	3
83	No pop-up windows are used?	4
84	Is application able to adapt when Web browser window is resized?	4
V	**Errors and their handling**	
85	Are error reports formulated in the way that the mistake is a fault of the system not of the user?	1
86	Are error reports grammatically correct?	2
87	Are error reports without exclamation marks?	1
88	Are error reports without vulgar and rude words?	2
89	If a mistake is found in input text field, is a cursor automatically placed into this field?	2
90	Do error reports provide any suggestion about cause of the problem?	4
91	Do error reports provide to the user ability to take back control over the system?	4
92	Is it possible to send an inquiry to an application provider?	3

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