

Heatmap Generation Techniques used for GeoWeb Application User-Interface Evaluation

Oldřich Horák, Martin Novák, and Vojtěch Zákoutský

Abstract—This article describes techniques of the heatmaps generation, and their implementation. The specific issues of the implementation in the web-based environment are discussed, and the special features of the using in the GeoWeb application are described. There are discussed the differences depending on the limited features of the web-application architecture, the possible solution using the web-browser scripting capabilities, and the impact on the GeoWeb application user-interface evaluation. In the conclusion, the future ways of the research are described and briefly explained.

Keywords—data processing, GeoWeb, GIS, heatmap, user-interface, visualization, web-application.

I. INTRODUCTION

THE Geographical Information Systems (GIS) are equipped with many types of user-interface (UI). The most popular interfaces have form of the web-page nowadays. Such system is called “GeoWeb”. It means the GeoWeb is developed in the form of the web-application (see Fig. 1) therefore it presents the results of the geographical services using the web-interface.

The user-interface is a very sensitive part of the GeoWeb application, because many people use it. If the service is public, the share of non-professional users can be considerable. Each one has other wants, customs, practices, and general behavior, when he/she uses the interface. Therefore, monitoring and evaluation of the user’s behavior at work with the interface is very important for the next development of the UI. [1, 2]

There are many technologies and techniques of the web-site or the web-page analysis. The user’s behavior monitoring is a special type of web-page analyzing. The GeoWeb UI can represent whole or a part of given web-page. Therefore, the web-page or its part should be monitored. [3]

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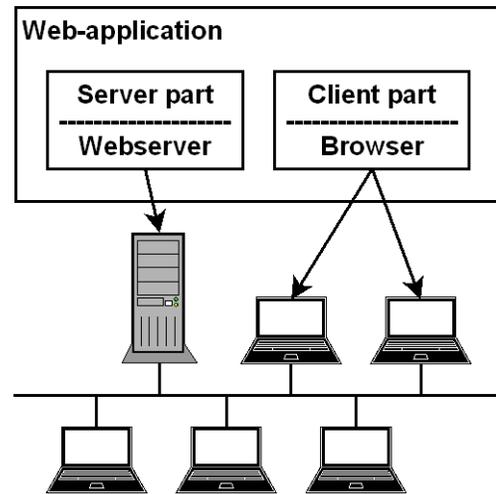


Fig. 1 Web-application Architecture

Of course, the common client of the GeoWeb application is realized by any type of web-browsers. But, the browsers’ features and capabilities are not primarily oriented to monitoring of user’s activities. There are very limited means of feedback from the client to server usable for an activity monitoring. As the common implementation of the web-application is based on client/server architecture (see Fig. 2):

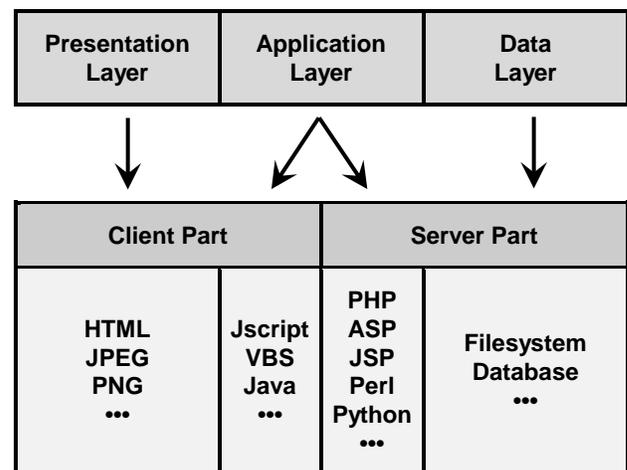


Fig. 2 – Implementation of the Web-application

There are three basic layers:

Data layer can be provided by the given server, but some data can be dynamically loaded or linked from another server or public services across the local network or Internet.

Application layer has to process the user requests and provide appropriate responses. This task is typically divided to be processed partly by server and by client side of the system.

Presentation layer is the user interface used to collect the request and to visualize the response. [4]

The only way how to monitor the user's activity is provided by the scripting tools of the application layer. It is possible to do it with the tools of the client part, server part, or both. The monitoring service can be implemented as the embedded part of given web-application or as the separate application. The obtained data can be stored within the web-application data layer or in the dedicated storage.

The next step of the evaluation is any form of users' activity visualization. A synoptic view can be the best way to provide the well-arranged survey of the activities. This form of data processing output is provided by the "Heatmaps" (see Fig. 3).



Fig. 3 – Heatmap over a Google Page [5]

Heatmap is a graphical representation of user interaction with graphical interface. In the case of click-monitoring it is the visualization of the click density. It means two-dimensional expression of the click rate on the given position in the web-page. There is easy to identify the parts or locations of the page that are most clicked or where the users click minimally (unused locations). The information is well represented by color-scale to be easy to understand (see Fig. 4). Locations

with a few clicks are represented by blue color that means "cold". Red color represents "warm" locations with a higher click amount. This "thermal" representation is the background of the term "heatmap". The heatmaps are often realized as semi-transparent layer over the webpage. The web-page parts are visible through the heatmap layer.

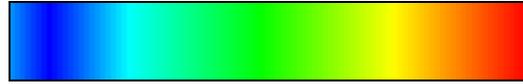


Fig. 4 – Typical Color-scale Used for Heatmaps

II. PROBLEM FORMULATION

There are some particular problems in using of the heatmaps. First, the recording of the user activity is limited by the features of the web-application scheme, and by the capabilities of the browsers. Second problem is the calculation of the heatmap server-side or client-side. The usability evaluation is the final scope of the exact using of the heatmaps technique.

A. Data Collection

The activity of the user consists of more parts. For the simplification, we can say there are two groups of user activity – input and output. The user receives the information from the web-page (i.e. reads the text), and pass some information using the input elements (writes text or clicks the links, etc). The monitoring of some activities can be difficult and needs some additional equipment to be connected with the PC. It means i.e. the eye-tracking technique of the monitoring of the user reading.

The monitoring of the user clicks using heatmaps doesn't need any additional expensive equipment or software. But, the capabilities of the browser provide limited space to realize the technique.

B. Heatmap Generation

If the data are collected, the calculation of the heatmap can be done server-side or client-side. The server-side generation can be less difficult, because the capabilities of the server part of the network application don't depend on the limited features of the browser. The client-side solution can be required as the more operative. Most of the clients provide scripting languages that can be used to heatmap generation, but the implementation using JavaScript or similar language would be very difficult.

C. Evaluation using Heatmaps

The heatmap provides the possibility to get the overview about the using of the particular components of the web-page. If the heatmap is used for the UI evaluation, the clicks in the active area (i.e. the map in the GeoWeb) must be removed from the heatmap generation, except of the clicks on the control elements (zoom, panning buttons, etc.).

This correction has to be completed before the heatmap generation and overall evaluation. The completed heatmap is then analyzed by human.

III. PROBLEM SOLUTION

The particular problems can be solved separately, but the generation can depend on the data collection. Some general techniques can be used for the solution, other has to be developed.

A. User Clicks Data Collection

The user clicks are detected by JavaScript on the client side. The coordinates relative to the origin of the web-page are passed to the server, and saved into the database.

TABLE I
USER CLICKS DATA COLLECTION METHOD COMPARISON

Feature	Method		
	AJAX Technique	<IFRAME> Tag	 Tag
Resources consumption per request	bigger	normal	less
Speed of request processing	slowest (browser dependent)	normal	fastest
Reliability	often data lost	sometime data lost	no data lost
Cross-domain request	mostly impossible (browser dependent)	possible warning (browser dependent)	possible

There are some options how to send the data from client to the server. Table I. gives the brief overview of the important features of methods usable for the data collection.

Using of the AJAX (Asynchronous JavaScript and XML) technique gives a solution of the data transmission [6]. But, some problems appeared by the testing of this technique. The collection of the user clicks on the web-page must be fast. The AJAX technology implementation speed depends on the type of browser, and some browsers manage the AJAX requests with random delay. It leads to data-lost, if the delay is too long. It depends on the reloading of the page by the client, when the server answer isn't received in the given time-limit, or the AJAX request queue is not transmitted completely before the reloading.

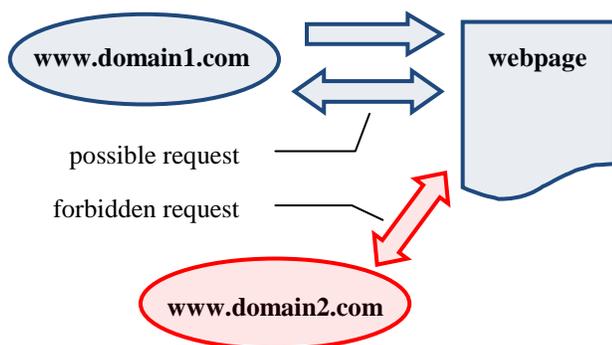


Fig. 5 – AJAX Request Restriction

In addition, some web-browsers have security restrictions to disallow the AJAX requests to the different domain (Fig. 5). Therefore, monitored web-page, or web-application, must be located on the same web-server as the heatmaps application. The AJAX technique was leaved after some testing, because of its unacceptable behavior and features.

The next possible solution for sending the data to the server is to use the IFRAME tag of the HTML. The content of this tag can be on the client side changed dynamically. For sending data to the server the GET parameters can be used. The IFRAME solution doesn't have any security restrictions of disallowing requests to the different domains in most of the actual web-browser types. But, in the latest versions of web-browsers this security restriction can be switch on. We cannot be sure with the IFRAME tag solution, that the all browsers collect all the wanted user clicks.

There is one another problem in the IFRAME tag solution. The content of the IFRAME tag managed as completely independent web-page by the browser. Therefore, the IFRAME content consumes some system resources, as memory and CPU time. If the web-page reload is needed frequently, it can take some additional time. We realized after some tests, the IFRAME tag solution is too slow and unreliable for our purposes.

Third possible solution is using the IMG tag from HTML language. This tag is used for inserting an image into the web-page. Web-browser gets the image from the server using the GET request. We can insert any parameters in this type of request and send data to the server this way. Example of GET request with parameters:

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The image source address can be changed via JavaScript and DOM (Document Object Model). The **script.php** processes the GET parameters on the server side, inserts the coordinates into the database, and returns a transparent image with size 1x1 pixel. This solution doesn't have problems with frequent reload and all data was transferred to the server quickly and completely in very most cases.

B. Heatmap Generation Solutions

User clicks data are stored in the database. Data in the database have the X and Y coordinates at least. It is useful to store some additional information, i.e. an ID of the user, date and time of the given user click, etc. User ID is generated on the server to distinguish between more users. A customized heatmaps can be generated with this additional data – for example the heatmap of given user clicks in specified day, and so on. The minimal structure of the database table has to have these elementary fields:

Position – the X and Y coordinate of the user's click on the web page stored in pixels as the distance from left and top edge of the browser's viewport

User ID – an automatically generated unique identification number; this identifier is also stored in the user’s web browser using cookie to identify the same user in the possible next request

Timestamp – actual time and date of the user’s click; it can be used to filtering or time analysis of the collected data

IP address – the particular (can be suppressed by proxy) identification of the user’s computer

Complete URL – it is useful to identify the page, where the user comes from, or which GET parameters are used in the page request (e.g. what keywords the user asks in the search on the web page)

Some additional data – for closer identification of the user (e.g. user agent string provided by used browser, DNS name of the user’s computer, etc.), or parameters of the web application (e.g. which layers was enabled/showed/displayed, which part of the map was displayed, zoom setting, which tool/icon/ was selected, etc.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	-3	-3	-2	-1	-1	0	0	0	1	0	0	0	-1	-1	-2	-3	-3	-4	-5
3	-3	-2	-1	0	0	1	1	2	2	2	1	1	0	0	-1	-2	-3	-3	-4
4	-2	-1	0	1	1	2	3	3	3	3	3	2	1	1	0	-1	-2	-3	-4
5	-1	0	1	2	2	3	4	4	4	4	4	3	2	2	1	0	-1	-2	-3
6	-1	0	1	2	3	4	5	5	5	5	5	4	3	2	1	0	-1	-2	-3
7	0	1	2	3	4	5	6	6	6	6	6	5	4	3	2	1	0	-1	-2
8	0	1	3	4	5	6	7	7	8	7	7	6	5	4	3	1	0	-1	-2
9	0	2	3	4	5	6	7	8	9	8	7	6	5	4	3	2	0	-1	-2
10	1	2	3	4	5	6	8	9	10	9	8	6	5	4	3	2	1	-1	-2
11	0	2	3	4	5	6	7	8	9	8	7	6	5	4	3	2	0	-1	-2
12	0	1	3	4	5	6	7	7	8	7	7	6	5	4	3	1	0	-1	-2
13	0	1	2	3	4	5	6	6	6	6	6	5	4	3	2	1	0	-1	-2
14	-1	0	1	2	3	4	5	5	5	5	5	4	3	2	1	0	-1	-2	-3
15	-1	0	1	2	2	3	4	4	4	4	4	3	2	2	1	0	-1	-2	-3
16	-2	-1	0	1	1	2	3	3	3	3	3	2	1	1	0	-1	-2	-3	-4
17	-3	-2	-1	0	0	1	1	2	2	2	1	1	0	0	-1	-2	-3	-3	-4
18	-3	-3	-2	-1	-1	0	0	0	1	0	0	0	-1	-1	-2	-3	-3	-4	-5
19	-4	-3	-3	-2	-2	-1	-1	-1	-1	-1	-1	-2	-2	-3	-3	-4	-5	-6	-7
20	-5	-4	-4	-3	-3	-2	-2	-2	-2	-2	-2	-3	-3	-4	-4	-5	-6	-7	-8

Fig. 6 – Example of Simple 1-point Heatmap

Data stored in the database can be visualized as the heatmap. The data are read from database into the two-dimensional array. The array is filled with zeroes before the generation starts.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
2	-3	-3	-2	-1	-1	0	0	0	1	0	0	-1	-1	0	0	1	1	0	0	0	-1	-1	-2	-3	-3	-4	-5			
3	-3	-2	-1	0	0	1	1	2	2	1	1	0	0	1	1	2	2	2	2	1	1	0	0	-1	-2	-3	-3	-4		
4	-2	-1	0	1	1	2	3	3	3	3	2	2	2	3	3	3	3	3	2	1	1	0	-1	-2	-3	-4				
5	-1	0	1	2	2	3	4	4	4	4	4	4	4	4	4	4	4	4	3	2	2	1	0	-1	-2	-3				
6	-1	0	1	2	3	4	5	5	5	5	5	5	5	5	5	5	5	5	4	3	2	1	0	-1	-2	-3				
7	0	1	2	3	4	5	6	6	6	6	7	7	7	7	7	6	6	6	6	5	4	3	2	1	0	-1	-2			
8	0	1	3	4	5	6	7	7	8	7	8	9	9	9	8	7	8	7	6	5	4	3	2	1	0	-1	-2			
9	0	2	3	4	5	6	7	8	9	9	9	9	9	9	8	7	8	7	6	5	4	3	2	0	-1	-2				
10	1	2	3	4	5	6	8	9	10	10	9	9	9	10	10	9	8	6	5	4	3	2	1	0	-1	-2				
11	0	2	3	4	5	6	7	8	8	9	9	9	9	9	8	7	6	5	4	3	2	0	-1	-2	-3					
12	0	1	3	4	5	6	7	7	8	7	8	9	9	9	8	7	8	7	6	5	4	3	1	0	-1	-2				
13	0	1	2	3	4	5	6	6	6	6	7	7	7	7	7	6	6	6	6	5	4	3	2	1	0	-1	-2			
14	-1	0	1	2	3	4	5	5	5	5	5	5	5	5	5	5	5	5	5	4	3	2	1	0	-1	-2	-3			
15	-1	0	1	2	2	3	4	4	4	4	4	4	4	4	4	4	4	4	4	3	2	2	1	0	-1	-2	-3			
16	-2	-1	0	1	1	2	3	3	3	3	3	2	2	2	3	3	3	3	3	2	1	1	0	-1	-2	-3	-4			
17	-3	-2	-1	0	0	1	1	2	2	1	1	0	0	1	1	2	2	2	1	1	0	0	-1	-2	-3	-3	-4			
18	-3	-3	-2	-1	-1	0	0	0	0	-1	-1	0	0	0	1	1	0	0	0	-1	-1	-2	-3	-3	-4	-5				
19	-4	-3	-3	-2	-2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-2	-2	-3	-3	-4	-5	-6				
20	-5	-4	-4	-3	-3	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-3	-3	-4	-4	-5	-6	-7				

Fig. 7 – Example of Simple 2-point Heatmap

Indexes of the array represent the coordinates X and Y from the origin of the web-page. Each one user's click is count in as the incrementing of the previous value at the given coordinates in the array. If two users click there in the same position, value 2 will be in the appropriate coordinates in the array.

After the data of the all user clicks are transferred from database to the two-dimensional array, the heatmap can be generated. It is necessary to create a new image with transparent or semi-transparent background. The heatmap itself is created by iteration over the array. Coordinates of array corresponds to the coordinates of the heatmap image. The values in the array represent colors from color-scale. Lowest value (e.g. 0) represents blue color, highest value (e.g. 255) corresponds to red color. Each one value from the array is recalculated according to “heat scale” to the related color. Examples of one and two point heatmap scheme can be seen in the Figures 6 and 7. When the whole array is processed, the final heatmap is generated to be ready to pass from the server to the client.

On the client side, the heatmap image is positioned as a layer above (or top layer) over the web-page using CSS. The user clicks are viewed just above the corresponding locations of the given web-page. This solution how to present the used, often used, or unused parts of the web-page is very understandable. Due to the transparent or semi-transparent background of the heatmap image, the rest of the web-page is still recognizable in the background.

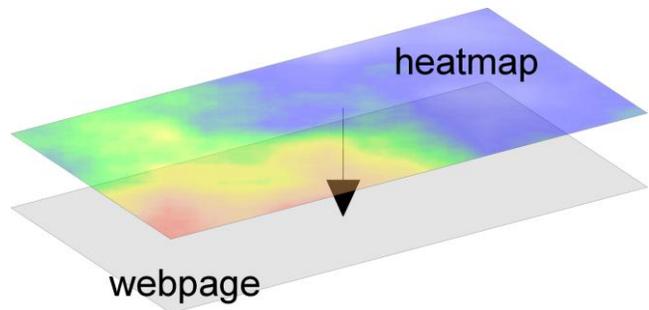


Fig. 8 – Heatmap over the Webpage

The Fig. 8 shows the using of the heatmap over the background webpage. If we want to set the location by the CSS features, the z-order attribute setting will be the best way how to get the final composition. However, other techniques can be used to layout the heatmap over the user interface.

C. Correction and Evaluation

The overview provided by the heatmap shows the using of the particular components of the web-page. For the UI evaluation the heatmap needs to be corrected by the leaving of clicks in the active area (i.e. the map field in the GeoWeb) before the heatmap creation.

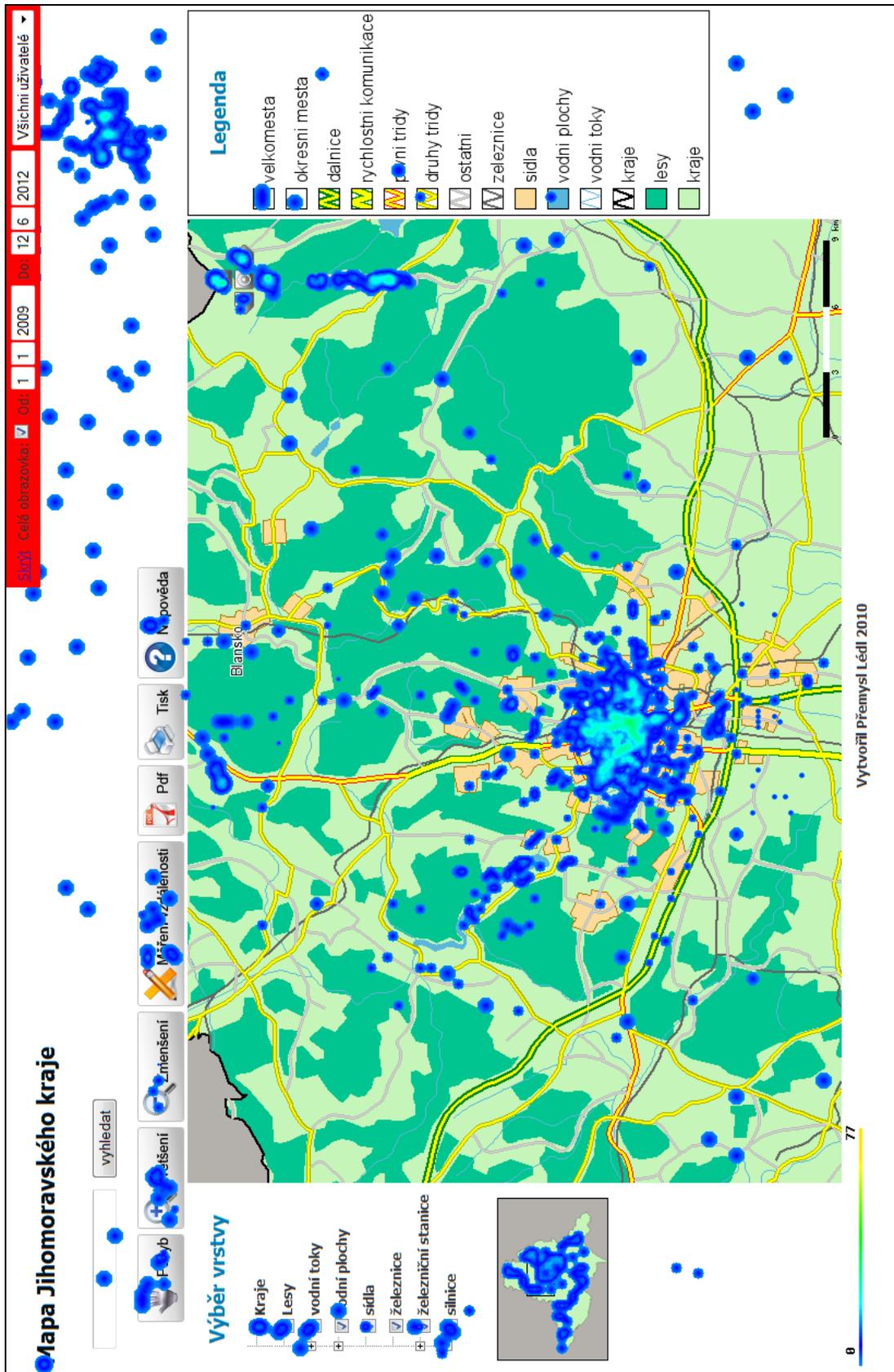


Fig. 9 – Heatmap before the Correction (generated using [7])

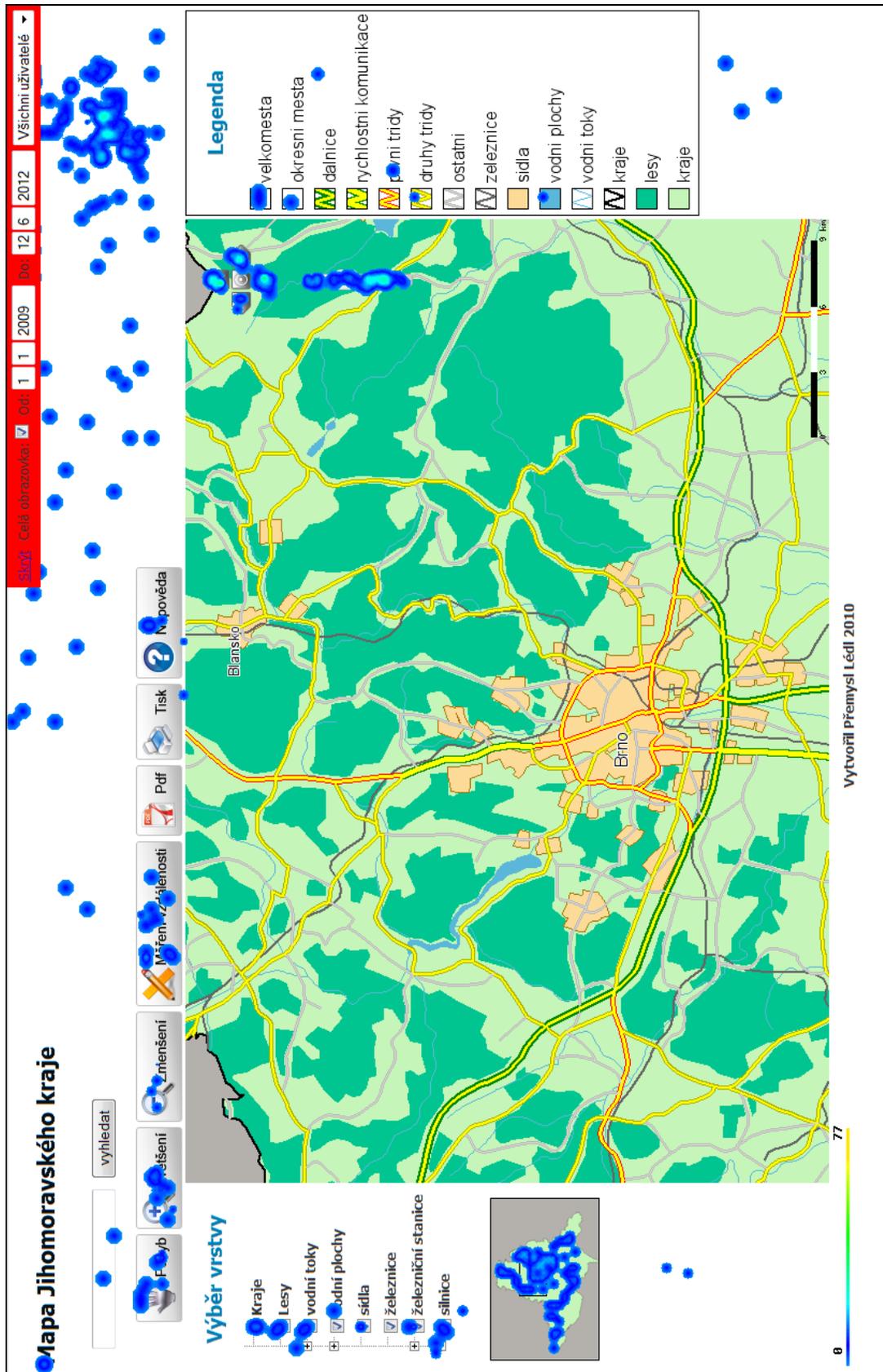


Fig. 10 –Heatmap after the Correction (generated using [7])

The correction is demonstrated on Fig. 9 (without the correction), and Fig. 10, where the clicks in the map area are removed before the heatmap is generated. The human analyze is not affected by the clicks in the map, and only the UI can be evaluated.

It means we have to prepare the definitions of control areas to be able to distinguish the proper clicks for selection. Any clicks in the active area have to be separated before the heatmap generation. It can be combined with the given GeoWeb application if possible [8].

The control areas can be defined as one complex mask for controls (buttons, sliders, links ...), or as separate masks for each one control element. The using of the mask can be seen in Fig. 11 to 14.

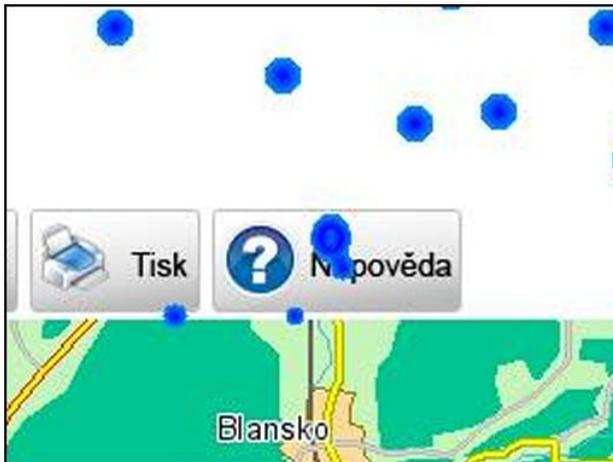


Fig. 11 – Example of Heatmap over Help Button

The Fig. 11 shows the unchanged heatmap around the Help Button in the control area of the GeoWeb application. We have to remove the click spots outside of the element. The basic way to do it is to use a simple bitmap mask as can be seen in the Fig. 12.

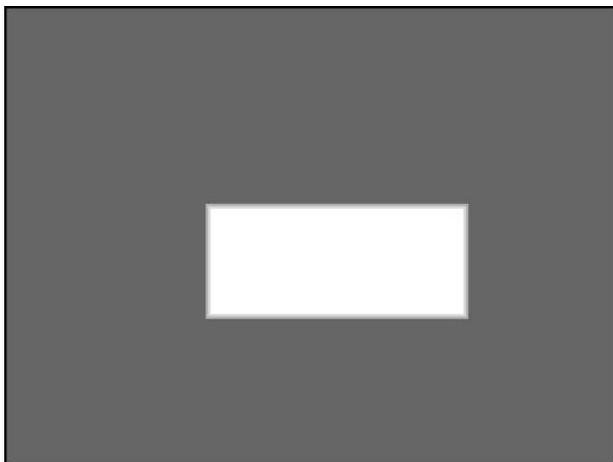


Fig. 12 – Example of Mask over Help Button

The mask can be drawn as a result of vector description of the control element area (the rectangle in this example). There is a possibility to use some level of tolerance in the click spots location (at the border of given element). If we allow it, the inner border of the rectangle can be drawn with smoothing. In this case we use gray scale representation of the mask. Otherwise, the black/white mask is sufficient.

The next Fig. 13 shows the using of the mask over the heatmapped webpage (composition of previous two figures). The click spots in the dark area will be suppressed for the final selected heatmap generation.

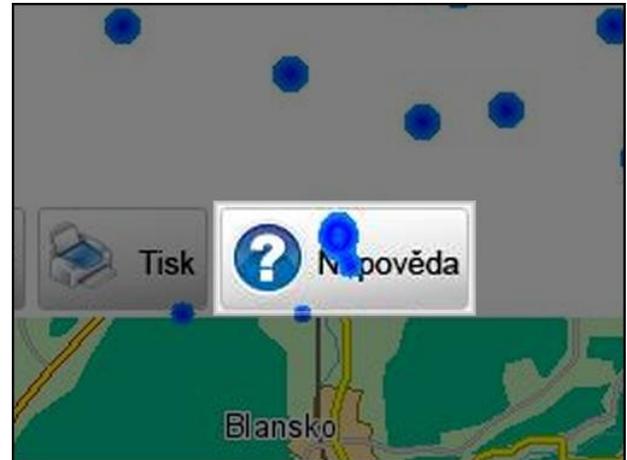


Fig. 13 – Example of Masked Help Button

In the final heatmap (see Fig. 14), the only given's control element click spots are to be seen. We can evaluate the using of this control element (Help Button in this case) separately.

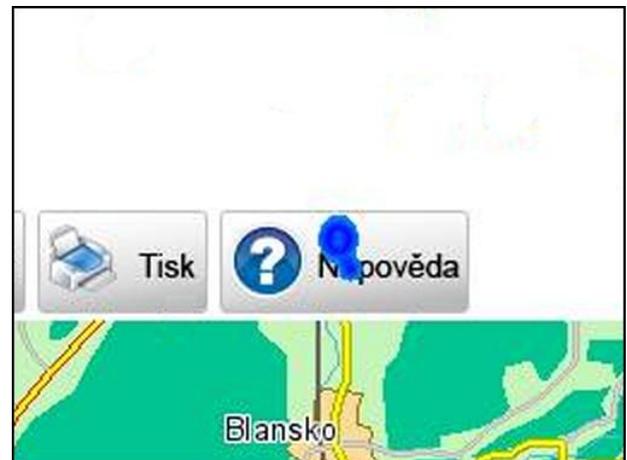


Fig. 14 – Example of Final Heatmap over Help Button

If we collect the separate heatmaps belonging to each one control element, then the complex user interface analysis can be provided for the UI designers to help them to develop the user interface better.

IV. CONCLUSION AND THE FUTURE WORK

The main task of the heatmaps using is get the overview about the user behavior and activity related to given UI (web-page) without special hardware or expensive software. The described solution uses the user clicks recording to the sufficiently predicative visualization method.

The solution uses the client/server architecture. The data collecting is solved on the client side by the JavaScript as the universal solution independent on the browser type. The server side provides database and PHP scripting capability for the data storing and the final heatmap generation. The heatmap is then send to the client and positioned over the original web-page using CSS attributes. The final view is simply understood and can provide good overview for the GeoWeb UI usability evaluation.

There are some recommendations and ways of support solution to distinguish the focused areas of the user interface of the GeoWeb application [9], and the web-application in general [10].

TABLE II
ELEMENTS OF WEB INFORMATION ARCHITECTURE [10]

Category	Attribute
Browsing support	Global Navigation
	Local navigation
	Context navigation
	Site map
	Site index
	Site guide
	Other navigation
Support of search	Search interface
	Search zone
Contents task	Headline
	Embedded link
	Embedded meta data
	Chunk
	List
	Continuous step Identifier

In the future it will be important to keep maximal platform independent solution. This heatmap application must still work in the different types of operating system and on the different browsers. The user discrimination with “different” web-browser is unacceptable.

More tasks are in the definition and evaluation of the parts of the user interface. The one of the ways is to enhance the set of elements of web information architecture (Tab. II) to be useful for the GeoWeb application. The similar description to [10] can be useful for the proper evaluation of given user interface in general.

The next area of extension is the using devices with touch-screen control and multi-touch interface. There are more evens than clicks leading to difficulties in the heatmap data collection. These new modes of application input require a new point of view on the user interface usability evaluation. We have to define new standards for the user interaction with the application, and redefine the static heatmap evaluation methods to be usable for the dynamic interface environment.

GeoWeb applications used i.e. in the information kiosks use the touch-screen control as a standard input. The UI usability evaluation provides the way to develop these applications better.

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