THE IMPACT OF INTERFACE ASPECTS ON INTERACTIVE MAP COMMUNICATION

An Evaluation Methodology

Lucia Peixe Mazieiro
Pontifícia Universidade Católica do Paraná PUCPR, Curitiba - PR, Brazil

Cláudia Robbi Sluter, Laura Sanchès Garcia
Universidade Federal do Paraná - UFPR , Curitiba – PR, Brazil

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Abstract: In this paper, we will present an analytical and methodological procedure to evaluate the interfaces of Interactive Maps. The main aims of one such evaluation is to (i) identify the essential aspects of these interfaces, (ii) investigate their influence on the communication with users and, based on this, (iii) set directives to guide the design of interfaces of future Interactive Maps. The process of evaluation leads to a detailed analysis of both the interface and the interaction itself. In order to do so, the process consists of the analysis of the essential elements of the interfaces, the evaluation of these aspects in relation to the users and, finally, the study of the results obtained. The results mainly refer to significant information on those aspects of the interfaces which, in turn, concern the necessary resources to both the interaction itself and the functionalities that Interactive Maps provide.

1 INTRODUCTION

Interactive Maps are cartographic products with a special mechanism that allows users to interact with a data base. “Interact” means, for instance, visualize different aspects of the same phenomenon, visualize information in different scales, choose a set of symbols for visualizing a certain area through different points of view and, finally, pan the map (Robbi, 2000). In other words, Interactive Maps (IM) are map-generating computational environments which enable users to interact both with the computational interface and with the map interface. This way, one can say that these interfaces allow communication processes to take place between users and map. However, each individual interface has its own set of features linked to the communication between IM and users. While the computational interface features show users how to interact with the IM, the map interface features concern the actual use of the maps, which must meet the users’ needs.

By introducing computational technology into Cartography, one expected to see differences in terms of the display of spatial information in maps because of, for example, the possibility of using new resources for map design and development. Nevertheless, many interactive environments merely present printed maps converted into digital format, not differentiating between IM and maps produced by traditional Cartography and not taking advantage of the benefits brought by computer resources.

According to MacEachren et al. (2001), maps designed to display characteristics and spatial phenomena still constitute a basic problem in Cartography. Nonetheless, by introducing interactive resources into Cartography, the focus shifts to problems in the field of Human-Computer Interaction (HCI). This way, within HCI users are taken into account from the very first analysis of the basic requirements for the development of a given computational system project to the usability evaluation of the final product (the computational system). In addition to HCI, another area that lends insight to the study of the difficulties and benefits of the interaction between IM and users is Cognitive Psychology. Cognitive Psychology examines the users’ cognitive processes during the interaction, including their at-

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tention, perception and memory when using the computational interface (Preece et al. 2002).

The problem we attempted to solve through our research lies in the definition of a methodology capable of identifying aspects which, in turn, enable communication in IM. Furthermore, finding out more about the influence of these aspects on communication also constituted an objective. In other words, we believe that by identifying the essential aspects within these interfaces and by analyzing their impact on user interaction, one can isolate the significant, necessary aspects responsible for enabling interaction – which in turn concern not only interactivity itself, but also other functionalities provided by Interactive Maps. The analysis of the results of this evaluation process revealed the reasons why certain aspects facilitate or hinder communication during the user-map interaction. Therefore, in the present paper we will describe our methodological journey of interface evaluation, which consists of the analysis of the essential aspects of these interfaces, the evaluation of these aspects taking the users into account, and the study of the results obtained.

The analytical and methodological path we proposed for assessing interfaces of IM environments shall lead to a full appraisal of the existing IM interfaces, indicating their essential elements, as well as the influence these elements exert on the user-Interactive Map interaction process. The main practical application of our research is the subsequent definition of a particular design standard which, in turn, assures the effective representation of the essential map elements, hence leading to an improved way of acquiring knowledge through future Interactive Map interfaces.

2 INTERACTIVE MAPPING

Thanks to the Internet, availability and integration of maps in interactive environments have recently soared. In these environments, users can access maps and interact with them by means of the interfaces. The maps available on the Internet can be divided into two categories according to their objective, namely Static Maps and Dynamic Maps (Kraak, 2000). Based upon DiBiase's (1990) cartographic visualization concept, cartographic applications may or may not enable users to access geographic data. Applications which do not enable this kind of access are targeted to cartographic communication only, i.e. the display of already known information. The applications which enable users to access geographic data, on the other hand, allow users to study the displayed information for research purposes, hence making it possible for users to acquire new knowledge about the map. In order to do so, the architecture of these applications consists of a series of media, and may additionally rely on geographic databases.

Internet interactive mapping has granted users many benefits, such as the easy access to cartographic information. Indeed, one of the main benefits of interactive technologies lies in the possibility of displaying cartographic information and promoting interaction in different ways (Preece et al., 2002). Despite that, what one mainly expects of the interaction resources of an IM is that they provide users with the necessary information to interact both with the computational and the map interfaces. In other words, communication in these interfaces must be adequate for each of the user-IM interaction moments. In this sense, the computational interface must work as a facilitator, allowing users to gain knowledge about the functionalities of the computational system and making their interaction with the map easier. Similarly, the cartographic language must also work as a facilitator, helping users to build their spatial knowledge through the map.

Millions of people access geographic information on the web on a daily basis, be it to check the weather forecast or choose the best way to a particular destination. What most of these people do not know is that, underneath the interface, what they are actually using is a System of Geographic Information (Harder, 1989). This means that in order for an Internet-based Interactive Map to work, it makes use of a series of technologies of interactive media, which in turn consists of a combination of different web software. Nevertheless, users have access only to the interfaces of the computational environments. The instances of mapping found on the web reveal a variety of both map display and map production techniques. Despite that, this variety of techniques is not applied solely to mapping; instead, they can be applied to any web-based product of any field of knowledge (Stevenson et al., 2000).

2.1 Computational Interface

Any interface offered to the public on the computer screen is in fact an image made up of signs. For IM, this image has two different spaces, namely one for the map and one for commands and functions for IM interaction. These two spaces are, in other words, the map interface and the computational interface.

In general, the computational interface can be subdivided into areas designed for the navigation

functions, general use functions and other functions, depending on which functionalities the IM offers. Users interact with these perceptible interface elements, which in turn are variable in the computational interface. These variations derive from different kinds of computational technology used to enable users to access IM through the Internet. IM can, for example, be interactive web pages in which an image is subdivided into a set of links that lead to other images every time users access such links.

2.2 Map Interface

Every project of this nature must take two basic elements of Cartography into consideration, namely spatial localization and the attributes of the features represented in the map (Robinson et al., 1995). However, when a map belongs to an interactive environment, the portion of the screen it takes up also includes the map interaction tools, such as the scale and the panning tool. Therefore, one such project must also include high quality interaction tools. The size of the map elements, for instance, must vary according to the scale chosen by the user.

As for the cartographic components themselves, they can vary depending on the purpose of the map. In other words, cartographers are responsible for choosing these components, and they usually base their decision on the target users' needs and expectations. This is the reason why there is no consensus in the specialized literature about which components a map must possess. According to Dent (1999), thematic maps must contain a title, key, scale, mapped regions, mapped symbols, toponymy, coordinates and credits, as well as information on its sources and date of publication. Despite that, a few other map elements can vary according to the users' familiarity with the mapped region. The North or scale indications, for example, are optional for those users who already know the mapped region (Slocum, 1999).

2.3 Interactive Maps: Communication

Within cartographic interactive environments, the perceptible interface elements are those which promote communication or interaction with users. They are representative information on the interface elements which, in turn, are essential for interaction. As such, these elements may also be referred to as communication components of the map interface. In the computational interface, on the other hand, the communication components are both the static elements of screen graphic design and the command elements of the tasks available, through which users interact with the map. These two types of elements consist basically of the interaction resources and functionalities provided by Interactive Maps.

Despite that, interfaces within Interactive Maps may display certain features which, in turn, trigger interpretation conflicts. This means that a given piece of information may hinder and even prevent users from grasping certain interface elements. For instance, it is well known that sometimes people do not see what is right before their eyes, or see what is not before their eyes – or even what they cannot see (Sternberg, 2000). Indeed, according to this author, the illusions triggered by certain images may have nothing to do with the users' background or knowledge, but rather refer to their perception of the stable relationships between the characteristics of the objects they see and the real world.

The users' knowledge about objects, concepts, relationships and process, amongst other things, has a great impact on the cognitive process that takes place during their interaction with the map. In fact, memory allows people to trace several kinds of knowledge derived from previous experiences and use them adequately in the present (Preece et al., 2002). This recalled knowledge is then associated to a new piece of information and rearranged in the brain together with new knowledge. In spite of that, MacEachren (1995) asserts that the process of map interaction is a complex problem of information processing, whereby users build a series of cognitive representations of what they see. He believes that these representations are then questioned within a framework of mental representations which, in turn, offer a context or set limits within which the conceptual image derived from the map can be understood. In this sense, the usefulness of the application of computational technology to Cartography depends greatly on the quality of the displayed information.

Even with ideal users (i.e. those who have a particular objective and know how to use the interface), the usability and speed of the interface depend on the effectiveness of its own communication – i.e. the interface elements. When the computational technology is useful for the interaction, this means that interface components of the Interactive Maps are effective, enabling users to easily fulfill their objectives within the IM. When technology is not so useful, this means that the interface elements are inadequate, requiring a closer inspection to find out where are why the technology is not being effective.

3 OUR PROPOSAL

The main research hypothesis that provides the very foundations of the present paper states that every Interactive Map interface must contain certain essential elements in order to enable users to successfully interact with the interface and fulfill their objectives. These essential elements are responsible for communicating to users how they must proceed to interact with the information displayed in the map. The selection button of an interface, for example, allows users to choose whether or not the map should display certain pieces of information. When users intend to make use of one such resource, they must promptly know to proceed in order for the interaction to be a successful one.

Interface evaluations are effective tools for determining users' preferences when they access an IM, or even to find out whether they use the IM efficiently (Preece et al. 2002). In this context, we designed a methodological and analytical evaluation procedure to examine the essential components of the IM interfaces, as well as their impact both on map use and on the computational interface. This evaluation process resulted in a detailed analysis of each interface and interaction steps. In summary, the evaluation method proposed here allowed us to identify the essential aspects of the interfaces and their effect on the communication process that takes place during the interaction with Interactive Maps.

The literature offers a number of interface evaluation models, which in turn recommend conducting tests and questionnaires with users so as to evaluate the interface usability in a cartographic context (Stephen, 1994, MacEachren, 1998, Stevenson et al., 2000, Hornbæk et al., 2002, Andrienko et al., 2002, Zhu et al., 2005, Koua et al., 2006). Despite that, there is a serious lack of evaluation methodologies, particularly in terms of the specification of the tasks to be carried out on user-based testing (Slocum et al., 2001; Koua, 2005). This means that recently only a few authors have published new methodologies for interface evaluation (Koua, 2005).

3.1 A Closer Look

Based upon the theoretical foundations provided by Human-Computer Interaction and the interface evaluations reported in the bibliography studied, we designed an evaluation procedure to analyze the effect of certain interface elements on communication within Interactive Maps. This procedure consists of three interdependent phases, namely IM interface analysis, evaluation of user interaction and analysis of the evaluation results (see Figure 1).

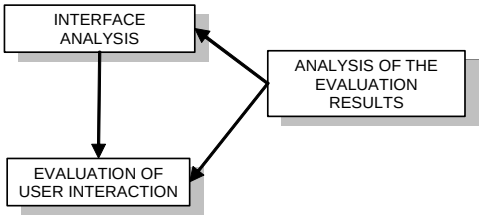

Figure 1: Evaluation procedure of IM interfaces the three phases.

During the first phase of the process we analyzed the IM interfaces in order to obtain a full appraisal of their available elements. This analysis allowed us to know the interfaces and spot design differences amongst them. After that, we studied the effect of these design differences on the users' cognitive process during the interaction, and this makes up the second phase of our procedure: the evaluation of user interaction. By having users take tests and respond to questionnaires, this evaluation enabled us to locate, based on the elements analyzed in the previous phase, the areas where interaction problems occur. Finally, we analyzed the information obtained in these two first phases (phase three).

The aspects we assessed comprise the elements and features of both map interfaces and computational interfaces with which users interacted. Identifying and appraising these aspects is essential for the design of future Interactive Maps. High quality interaction means the fulfillment of the users' objectives efficiently and effectively.

3.2 Interface Analysis

The evaluation model consists of an investigation of the existing Interactive Map interfaces. The aim of the evaluation is to analyze the way in which both the map elements and the elements of the computational interface are allocated in these interfaces. This investigation is targeted to determining, through these map and computational interface elements, the aspects in which IM are different amongst themselves. It seems to us that these differences derive from the lack of established design guidelines, possibly leading to usability difficulty.

The investigation itself is a thorough analysis of those aspects of the interfaces responsible for communication, as well as of their inherent characteristics. Preece et al. (2002) emphasize that an investigation is a process whereby the designer plays the role of a user following a particular learning model.

In the present research, the object of the investigation is the communication components provided by the interfaces under analysis.

Initially, we came up with a data bank of the interface aspects to be analyzed –i.e. the communication components of the map interface, together with a set of commands and functionalities available on the computational interface and targeted to user interaction. The next step consisted of analyzing the interfaces in question for the abovementioned elements, taking note of their presence or absence. Finally, the investigation process resulted in a thorough analysis of all design features of IM interfaces developed recently.

Within the set of elements of the computational interface, we took into account both the interaction elements and the map navigation functions. This set of elements basically refers to interaction styles, including the following tasks: filling out forms, clicking buttons, checking check boxes, selecting from lists, selecting from pull-down and pop-up menus and clicking links. The basic navigation functions we analyzed, on the other hand, comprise those resources which allow users to display the map differently, namely zoom in, zoom out, zoom scale, vertically and horizontally dragging the image (through arrows), panning in any direction, displaying the image in its initial scale.

As for the map interface elements, we considered the perceptible elements responsible for communication within the map, i.e. the typical map components. According to the literature in question, the set of typical map elements is made up by the title, the mapped region, the key, the sources, the North indication, the graphic scale, the numeric scale, the geographic coordinates, the toponymic elements and the date of publication. In addition to these map interface components, there are other IM elements which can be taken into account, such as the presence of Remote Sensing images, additional information on map features, and a map of general localization.

3.3 Evaluation of User Interaction

By taking the aspects of the IM interfaces analyzed in the previous phase into account, we evaluated, in this second phase, how these elements make it easier or more difficult for users to fulfill their objectives with the IM. Our main usability parameter was effectiveness, since only effective IM can provide users with successful interactions.

According to Preece et al. (2002), by using tests one can learn more about the users' performance in the application, whereas by making use of questionnaires and interviews one can learn more about the users' opinions on their performance. We rated the effectiveness of the interfaces by analyzing to what extent they allow users to fulfill their interaction needs, hence enabling them to reach their objectives. In addition to tests, we also used questionnaires to obtain more information from users about their performance while taking the tests.

One task included in the test is, for example, identifying a map symbol by referring to the key. To lend more insight to the test results, we asked users to rate the level of difficulty of reading map symbols, reading key symbols and, finally, associating map symbols to key symbols. These additional pieces of information obtained through questionnaires shed light on the reasons why users were able or unable to correctly carry out the tasks – in this case, identify map and key symbols. Therefore, the users' remarks can be perceived as a part of the tests. However, they can only be used when a usability lab containing this application is available (Preece et al., 2002). In summary, the users' informal remarks allowed us to add more insight to our evaluation.

During this second phase of the evaluation process, each test was designed according to the information obtained in the previous phase, so as to examine the impact of the interface aspects analyzed on the interaction between user and map, and between user and computational interface. This way, the tasks included in the tests consist of actions to be carried out during map interaction. These actions belong to the set of basic actions that can be carried out on the map interface, including the identification and categorization of map features, as well as data comparison (Koua, 2005). Based upon this set of basic actions (which can also be defined as conceptual objectives), we sketched the resulting actions of the users' mental processes while using the map. In order to evaluate these actions, which in turn take place during the actual computational interaction, we examined the cognitive process behind the use of the interactive functionalities.

Our intention with this evaluation model with tests and questionnaires was to examine, at first, to what extent the interface aspects hinder or facilitate the use of the interface and then, with the users' opinions, how exactly the interface hinders or facilitates the interaction. Take, for instance, a situation in which a user could not find, in the interface, an element mentioned in the test, but the answer to the test question was actually in the interface and s/he simply could not find it. In this case, the remarks obtained through the questionnaires help to throw light on the real causes of the problem.

All tasks we included in the tests were easy, simple tasks which directed users straight to map use. Each of the tasks was designed according to the set of basic actions that can be carried out both on the map and on the computational interface, so as to examine each and every element pointed out in the first evaluation phase. Each task stated what the users were expected to do, and was followed by questions on the users' opinion about the task itself and their performance. This way, the tasks guided the users through the main actions within the IM, hence providing them with the necessary experience to answer to the subsequent questionnaire. When a task asks users to display a certain region and answer questions about the location of the mapped region by reading the cardinal points, a correct answer indicates that the user was able to successfully read the location requested. However, it could be that the user already knew the mapped region, and therefore did not rely on the map features to carry out the task. In any case, not all users know all mapped regions mentioned in the task and even the ones that do, do not answer the questions in the same way.

We designed the general test model according to the information obtained during the first phase of map evaluation. The model was structured around the previously evaluated interface aspects, the tasks that can be carried out in relation to each of these aspects, the presence of features surrounding each of these evaluated aspects in the main IM interface and, finally, the features surrounding IM interaction. In order to evaluate the interface in terms of the mapped region, for example, we examined all tasks involving map visualization and map features, as well as the identification of such features. Our hypothesis was that the IM displays, already on the initial interface, the necessary resources for spatial localization and identification of map features. When not, these resources can then be obtained through the interaction. This way, other aspects end up being evaluated as well, amongst which are symbols in the key, the IM title in relation to its use and function, the graphic scale (and to what extent it helps users to relate and visualize map elements), the North indication and the presence of geographic coordinates (and their contribution to map orientation), the toponymy (and to what extent it helps users to find and recognize map features), the Remote Sensing images (whether they work as an additional resource for distinguishing between map elements), and the sources and updating dates (whether the IM displays the correct sources of the information it contains).

For the evaluation of a certain IM, we structured the test according to its particular interactivity features, as well as according to its application sequence. Once the test phase was completed, we collected all the information obtained and systematized it in spreadsheets. Next, we counted the number of users and the number of correct answers. We attributed percentages to each and every task so as to make it easier to compare the different tasks and different users' profiles. Finally, we analyzed and grouped the questionnaire remarks, hence forming different opinion groups amongst the users.

3.4 Analysis of the Evaluation Results

The main aim of this analysis is to find out which elements may affect interface usability and why. The flowchart shown in Figure 2 shows the initial steps of the analysis, namely the comparison between pieces of information concerning the same IM. In other words, this step consists of the comparison between the information obtained for each interface aspect during the first investigation phase and the results obtained in phase two, the interaction with users. This analysis results in a set of information on the evaluation of each IM, making up a sort of mapping of its interaction pros and cons. This mapping will work as the basis for the next analysis step.

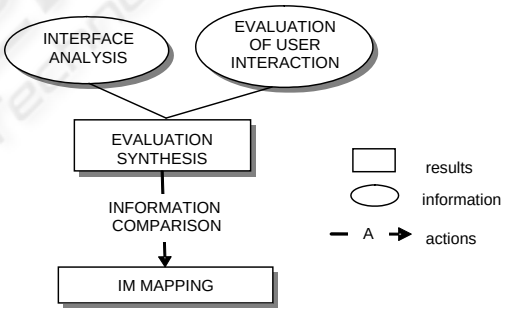

Figure 2: Flowchart of the IM evaluation results.

Based upon traditional Cartographic theories, which in turn define the representations of the aspects we evaluated in the maps, we conducted the second analysis step. This second step comprised the discussion of the information obtained for the different interface aspects we evaluated. One such discussion consists of a comparison amongst the different IM mappings, as shown in Figure 3.

It was during this second analysis step that we tried to identify the reasons why certain aspects seem to hinder or facilitate user-map interaction. Furthermore, we defined the structure of the evaluated aspects which, in turn, enable users to carry out tasks within the IM. The information we ob-

tained here is essential for the development of guidelines for the design of future IM interfaces.

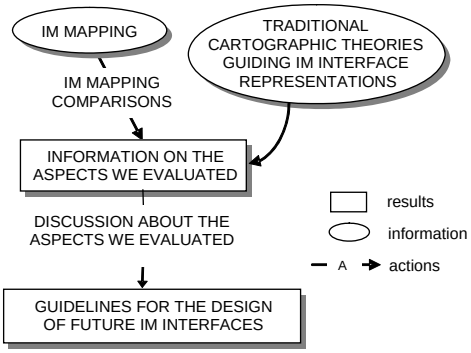

Figure 3: Flowchart of the analysis of interface aspects.

4 PROPOSAL VALIDATION

The procedure we proposed here consists of a model of IM interface evaluation for obtaining qualitative information on the communication aspects of these interfaces. The concepts derived from Human-Computer Interaction offer the foundations of the procedure, together with the experiences involving Interactive Map evaluations reported in the specialized literature. This evaluation procedure comprises an initial phase of IM interface analysis, a second phase of user interaction evaluation, and a third phase of analysis of the evaluation results.

The investigations we conducted on IM interfaces took into account certain development and functioning features of a set of Interactive Map interfaces. This way, our aim was to check the communicability of these IM interfaces in terms of “which are” and “where are” the communication and interaction elements of the IM interfaces. Thanks to this initial investigation we arrived at the design features of the IM interfaces in question. One of these features, analyzed through the aforementioned methodology, was that most IM provide users with tools that allow them to simply see the information; in other words, in the context of cartographic visualization, they are maps for cartographic communication. In these IM, users cannot navigate or obtain further details about the information displayed on the map, but rather merely see its image. This discovery led us to the conclusion that most Internet-designed IM are limited in terms of functions and other complex operations. The results of interface analysis also point to the similarities and differences between the different IM interfaces evaluated. Indeed, the fact that there are differences indicates that the design of these IM interfaces did not follow a pattern. In other words, the development of such environments is not guided by specific design guidelines. Hence one can say that designers do not know the exact purposes and uses of Interactive Maps. In general, when users can carry out tasks with which they are familiar, both the cognitive process and the interface use are easier and quicker.

The evaluations of user interaction, on the other hand, allowed us to check to what extent users understand the interface aspects we investigated, as well as to what extent they hinder or facilitate interaction. In other words, we evaluated different aspects during the interface analysis phase (both the ones common to all interfaces and the different ones) and then examined their impact on communication during user-IM interface interaction. One example is the evaluation of the key of symbols. During the second phase, users were asked to write the meaning of the symbols used in the map, which they did without difficulty. However, they did have difficulty matching map symbols and their respective key. This difficulty indicated that they are problems in the use of keys of symbols in IM. To make matters worse, in another task most users were not able to find the meaning of the map symbols even though the IM contained a key of symbols. After this second task users were also questioned about the difficulties they faced reading map and key symbols. In both tasks, they claimed that they had no difficulty at all reading map and key symbols separately, but felt completely unable to read them comparatively or match them. In this case, users were able to recognize and correctly read map symbols, such as road and vegetation symbols. However, not only did they recognize these symbols, but they also classified them without actually referring to the key. This perception characteristic can be explained by Marr’s theory (1982), whereby recognizing and classifying symbols is an understanding process which, in turn, is influenced by the light intensity of the symbols, as well as by their shapes, orientation and discontinuances, amongst other things. Only after this process of recognition will the operation of symbol reading go through other steps of the cognitive process. This way, the use of symbols with which users are familiar leads to an easier and quicker reading of the symbols.

5 CONCLUSIONS

The evaluation procedure proposed here helps to obtain extremely valuable knowledge about several

different aspects of the IM interfaces, particularly of the map components and the computational interface components with which users interact. This knowledge, in turn, is paramount for the establishment of design guidelines for interfaces of future Interactive Maps. Indeed, the main purpose of such guidelines would be to work as reliable a reference, something IM interface designers could refer to and base their design decisions on.

The methodology we proposed for the evaluation of IM interfaces enabled us to identify the situations in which the interface aspects under evaluation facilitate the interaction. The results of the evaluation process indicated that most users do fulfill their initial objectives with the maps, which means that most design decisions have a positive impact on user-interaction and, therefore, should be adopted as models for the development of future IM interfaces. On the other hand, the evaluation did reveal that there are situations in which even though users do manage to fulfill their objectives, they have difficulty carrying out the necessary tasks. This means that the interfaces have problems, and new studies have to be carried out in order to find out more about them and their solutions.

In conclusion, we can say that interface aspects cannot be evaluated solely according to the effectiveness of the interaction (i.e. the fulfillment of test tasks) because the users' opinions lend significant insight to the research (through the subsequent questionnaires). Only with a more comprehensive set of information about IM interfaces can one actually learn more about the use of Interactive Maps.

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