

EVALUATION OF USER INTERFACES FOR GEOGRAPHIC INFORMATION SYSTEMS: A CASE STUDY

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Abstract: This paper presents an evaluation of user interfaces of two Geographic Information Systems (GIS) tools, ArcView and Spring. This work is related to a specific characteristic of those interfaces, which is to allow the user to view a map. User interfaces were evaluated based on the main cognitive difficulties related to the execution and evaluation bridges employing a cognitive engineering approach and, complementarily, in accordance with the semiotics engineering parameter called “system communicability”. Both evaluated systems are generally considered to be quite complex, not only in terms of understanding the interaction elements present in the interface, but also the knowledge embedded in the tasks that can be accomplished by these systems. Although the study described in this work was focused on a single task it confirmed the general opinion about these kinds of applications: a novice user cannot explore them without some assistance from an expert user or by studying books and manuals. Even an expert user usually faces significant difficulties using those GIS tools.

1 INTRODUCTION

This paper presents the results of an evaluation of the user interfaces in Geographic Information Systems tools, ArcView and Spring. ArcView is commercial software developed by ESRI - Environment Systems Research Institute (www.esri.com). Spring is free software developed by INPE - National Institute for Space Research, Brazil (www.inpe.br). The main research goal was either to prove or to reject the popular idea about the impossibility of overcoming the difficulties of using either of these tools. The relevance of this study is based on the assumption that a poor and difficult interface is not a consequence of the system complexity but a result of an inadequate interface design.

Due to the inherent large number of interaction possibilities of these tools, this work was limited to those interfaces designed to allow the user to view maps from stored data. Even if we consider that this kind of tool is designed for specialized users, the option for a simple task evaluation is justified because of the direct relation between the complexity of the task and the difficulties of the interface design process. So, if a simple task proves to be difficult to be accomplished a more complex task will certainly be also difficult.

The user interface evaluation was based on the main cognitive difficulties related to execution and evaluation bridges, based on the Cognitive Engineering (Norman, 1986) approach. The quality of the interface environment was complementarily evaluated in accordance with the Semiotics Engineering parameter called “system communicability” (Souza, 2005).

According to (Burrough, 1986), GIS is “a powerful set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes”. These GIS characteristics make them powerful tools for decision-making and are widely employed in areas such as environmental and urban and regional planning. In order to evaluate GIS interfaces, it is useful to understand one difference between these types of tools and map viewer tools. Map viewer tools allow their users only to view maps from a database. The user cannot change the stored data. On the other hand, GIS has tools that can be used for manipulating, and thus changing, the data.

1.1 ArcView and Spring

ArcView is a tool that allows the user to explore, analyze and depict geographic data. Any users, even

those who do not have a solid background in cartography, can generate maps and manage spatial data. Users with knowledge on GIS and cartographic theory can easily integrate spatial data from different sources and with different characteristics in order to develop spatial analysis. ArcView software is compatible with several different operational systems such as Microsoft Windows, Apple Macintosh and Unix variants. ESRI has also developed a programming language, Avenue, for customizing ArcView applications (ESRI, 1996). Spring is also a GIS application that allows its user to explore, analyze and present geographic data. It is possible to install and run Spring software on different platforms, from microcomputers to high performance RISC workstations, at the same level of efficiency. It also runs on different operational systems, such as Microsoft Windows or UNIX. Spring has a number of different tools for manipulating spatial data, for example spatial indexes, image segmentation and classification, or digital surface model generation. One of its most important characteristics is that it is free and can be downloaded from the INPE Internet site (INPE, 2005). Both ArcView and Spring have a great number of computer capabilities, which makes possible the accomplishment of multiple user tasks. We describe some of those capabilities below as an example of their potential (ESRI, 1996; INPE, 2005):

- Map generation: to view or to edit maps, and to add data to them from a database;
- Generating new information: to generate new information from graphic (vector and raster data) and alphanumeric databases by using spatial analysis tools. These data can be stored in software (ArcView or Spring) file extensions, can be imported from other softwares or even from Internet sites. Data integration is based on geographic position data (geographic coordinates);
- Spatial trend evaluation: to manipulate geographic data and to allow the user to generate spatial phenomenon process models. Spatial phenomenon models can reveal unknown process trends which can provide important information to decision makers;
- Map presentation: to prepare map layouts in order to print them or view them on a computer screen along with graphics, tables, pictures, etc.

2 STATE OF THE ART

2.1 Related Work

A research described in (Prado et al., 2000) was based on viewing and interpreting maps as communication ac-

tivities about natural facts of the real world. The main research goal was to evaluate the expressive power (and the expressive limitations) of GIS tools. The analysis of ArcView 3.0, Idrisi 2.01 and Spring 3.2 leads to the specification of the discrete common elements (i.e. icons) present on a GIS interface. Other studies, from which we can quote (Schimiguel and Baranauskas, 2002) are also oriented to the semiotic analysis of the interface signs, in order to figure out which of the interpretation aspects are presented on the interface and their implications in the system communicability.

The work (Seixas and Souza, 2004) proposes an evaluation method for interfaces in which maps are involved. This method (ISIM - Interfaces Semiotic Inspection of Maps) also adopts the Semiotic Engineering approach. It evaluates the interaction quality based on the task of locating or defining roots in maps by identifying the presence of discontinuities in the interaction that affect the user comprehension of the system. ISIM uses analytical techniques for the application context definition and empirical techniques for testing the tool by real users. This work shows a class of common problems related to the interaction process with maps tools, more precisely the zoom functionality and the sign changes. Our work complements these results, showing critical problems in a very simple task.

In general, global interfaces evaluation methods demand for the consideration of the user knowledge background, that is, experts or common users (Prates and Barbosa, 2003). This was done in the present work, in the sense that the selected task (viewing a map) was well-defined and established as a potentially first task to be developed within any possible context of real use.

2.2 Theoretical Bases

We developed this work based on cognitive and semiotics engineering approaches. The Cognitive Engineering has provided the main theoretical support to the Computer-Human Interaction research area for the last three decades; the Semiotic Engineering has been recently consolidated as a sound theory which complements the cognitive approach, by granting a rather complete view through an integrated evaluation process.

According to Cognitive Engineering (Norman, 1986), when the user interacts with the software he/she crosses the "execution gulf" and the "evaluation gulf" (Figure 1). In order to cross those gulf bridges the user has to: a) Define his/her aim: which goal he/she wants to achieve; b) Formulate an intention: take a decision about what to do in order to achieve this aim; c) Translate his/her intention into system routine tools; d) Execute the action in the sys-

tem; e) Understand the system state; f) Interpret system behavior; g) Evaluate results in relation to his/her initial aim. User tasks, from (a) to (g), are parts of a process that are designed to cross the “execution gulf” and the “evaluation gulf” (Figure 1).

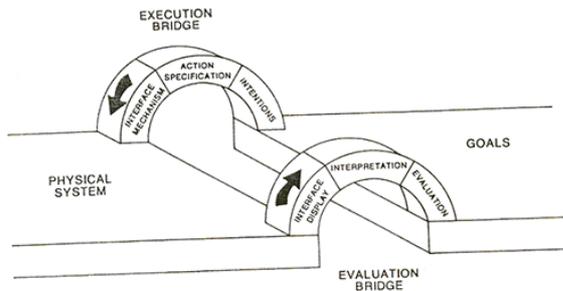


Figure 1: Execution and evaluation gulfs (Norman, 1986).

Semiotics Engineering (Souza, 2005), which is based on these Cognitive Engineering concepts, considers the user-interface as a message (or a set of messages) that is sent from the interface designer to the user in an asynchronous and unilateral way. According to this approach, the challenge for the interactive environment designer is to answer, by an interface language, two fundamental questions:

- What is the designer’s interpretation of the user problem?
- How the user has to use the system in order to achieve his/her goals?

According to Semiotics Engineering, the term “usability” is enhanced by the term “communicability”, which is related to the system’s capability to provide the user with answers to these two basic questions above. Communicability is related to the user’s ability to understand the interface design as the designer planned it (Souza, 2005). The more the user understands the designer’s reasoning embedded in the application, the more the user can use the application in a creative, efficient and productive way. The design should allow the user to understand how he/she should interact with the application and to understand the designer’s interpretation of the problem to be solved at every step along the interaction way. Bad communicability causes breakdowns in the communication process between the designer and the user and negatively impacts the efficiency in the user-system interaction.

The paper (Silveira, 2002) identified interaction breakdown situations (Winograd, 1996) based on system user tests, and proposed a set of statements related to each problematic situations. According to

(Souza, 2005), there are 13 basic communicability utterances that characterize breakdowns in user-system communication:

What is this? – Why does not it? – Help! – Where is it? – What now? – What happened? – Oops! – Where am I? – I cannot do it this way – Thanks, but no, thanks – I can do otherwise – Looks fine to me – I give up.

This set of utterances emerged from an empirical study involving real world users. The designer can use these statements as a core set in order to select those which could in fact occur during the interaction with a certain tool. The selected statements can be used to prevent and/or deal with eventual communication breakdowns.

The “scenarios” technique was used in order to specify a number of possibilities for user -system interaction states based on the knowledge about the users profile and the expected system tasks. In other words, each “scenario” was built from the authors’ previous substantial observation of communication breakdowns during these tools use, together with the authors’ systematic analysis of the whole process needed to perform the selected task, which determined the suitable utterances (Carrol, 1995). “Scenarios” are textual or pictorial descriptions of organizational uses of the application. “Scenarios” can be built for computer systems (interface evaluation) or for human organizational procedures (interface design). For systems’ evaluation, “scenarios” can be useful tools for identifying, analyzing and evaluating system uses. They allow the designer to use opinions, critiques and suggestions about the system in order to improve the system interface.

2.3 Methodological Steps

In order to define the steps of this work, we made two assumptions. First, the level of difficulty of the task developed by the user would be similar for both ArcView and Spring. Second, the user would not be an expert in cartography or GIS, and would never have been exposed to this tool. Therefore, the first step was to define the task to be carried on, considering that the user would not use any kind of help or tutorial.

The next step was to identify the possible difficulties the user would face when he/she is required to accomplish any task. These difficulties are related to execution and evaluation gulfs. In order to identify user difficulties, we designed “scenarios” that represent every predictable step the user would try in order to accomplish the required task. Because of the cognitive difficulties inherent in the tool it is possible that the user is not able to cross the execution and evaluation gulfs at his/her first try. The user then would need

to make multiple attempts to cross those gulfs using different tasks/actions. This process would occur as many times as necessary in order to achieve user goals. This situation can be represented by “abductive reasoning” (Souza, 2005), where several possible future actions can be imaged by the user. Every time the user is not well succeeded in achieving his/her current goal, he/she changes his/her goal and tries to cross those gulfs again. This process ends when the user’s goals are accomplished and the gulf bridges are crossed.

The book (Souza, 2005) defined two main levels of designer messages to the user: *strategic level* and *operational level*. The strategic level is characterized by a meta-communication, which helps the user to decide about choosing tasks to efficiently achieve his/her goals. Operational level messages must be able to maximize the communicative capabilities of the interface elements in every moment of user interaction. We propose here an intermediate level in which system tools communicability is evaluated. This intermediate level is understood as the level of system support for specifying and evaluating user actions.

In this work, system communicability was analyzed according to the level of cognitive difficulty. For every user interaction, we verified the kind of messages available on the system interface in order to analyze the interface communicability. Then, we registered the information acquired from this analysis in evaluation tables.

3 EVALUATING THE USER DIFFICULTIES

The user task selected for evaluating the ArcView and Spring systems was simply to view a map on a computer screen. The map was generated from a set of data that was stored in a CAD (Computer Aided Designer) format file. In order to show the methodological steps in all their deepness, we describe the whole process carried on with ArcView system. A similar procedure was developed with Spring. To achieve his/her goal to view a map on a computer screen, the user needs to take the following steps:

1. When the user begins the interaction process to view a map, the first question is “what can I do to view the map on the screen?” At this moment the user faces the first difficulty related to the execution gulf, which is “which action to take”. The user needs to identify the available interface tasks/actions and find out which one will allow him/her to achieve his/her goal. He/she makes the assumption that he/she is able to identify the

right tasks/actions to use by looking at the interface. This scenario is described in Table 1.

The interaction breakdown is probably caused by a system communication fault. The main problem is regarded to the execution gulf at this interaction moment and consists of a lack of interface communication at the strategic level which would indicate to the user what to do to achieve the intended goal (i.e., to draw the map on screen). A message describing the sequence of actions would help the user in identifying the whole procedure to be followed in order to draw the map.

2. The user returns to the initial goal and redefines his/her aim in order to “find the button on the interface that draws the map”. The user crosses the execution and evaluation gulfs of the new aim, but does not achieve the goal. Because the user tries some different actions (buttons), he/she acquires some knowledge about the interface. Among those available buttons he/she tries the *add theme* one, which can be the one to use in order to achieve the goal. This scenario is described in Table 2.

The problem here is most likely caused by a lack of communication related to the level of supporting user actions (intermediate level). There is no information on the interface that tells the user what each button does, which makes the task execution difficult. Nevertheless, there is some system support for crossing the execution gulf related to highlighting some buttons, the only ones available to start any task on ArcView (action supporting level).

3. The user accomplishes a new gulf crossing and redefines his/her aim, which is now “to add a theme”, one of the available buttons. The user crosses the execution gulf but the map is not drawn on screen, which corresponds to an evaluation gulf. Instead, a dialogbox appears on the screen that displays a message to the user. However, the message is not clear enough to allow the user to understand the result of his/her action (pushing the *add theme* button). The user has some difficulties in knowing if the action will accomplish the task that makes it possible to achieve the goal, and to know if he/she must do something else at that moment, like performing some action in the dialogbox. This scenario is described in Table 3.

At this time, after the user has tried some actions, an operational fault occurs due to misleading button labels. The label for the right button should be something like “select the map data file”. Once more the system fails at the action support level, as it does not display some advising message to the user related to the actions he/she should take.

4. The user accomplishes a new gulf crossing and redefines his/her aim, which is now “to look for the

Table 1: Scenario 1.

Goal		View the map on the screen
Execution	Intention	Draw the map on the screen.
	Actions specifications	Find the appropriate action on the interface.
	Execution	Check the available interface actions and select one (<i>Where is it?</i>). At this moment there is a cognitive difficulty which results in an interaction breakdown because the user could not identify the appropriate tool for accomplishing the intended goal.
Evaluation	Perception	Some buttons are highlighted.
	Interpretation	The highlighted buttons must indicate the available actions.
	Evaluation	It is not possible to evaluate the result because none of those actions are suitable to accomplish the task.

Table 2: Scenario 2.

Goal		View the map on the screen
Execution	Intention	Find the one button on the interface "to draw the map on the screen"
	Actions specifications	Read the labels of the highlighted buttons
	Execution	Point the mouse on the buttons in order to read their labels (<i>What now?</i> , <i>Where is it?</i>). At this moment there is a cognitive disconnection disconnect which results in a interaction breakdown because the user could not identify the appropriate tool for accomplishing the intended goal.
Evaluation	Perception	The user notices that there are 5 available buttons on the interface: <i>save project</i> , <i>add theme</i> , <i>help</i> , <i>text</i> and <i>draw point</i> .
	Interpretation	The <i>add theme</i> button must be the one to draw the map on screen.
	Evaluation	The evaluation is not efficient because the user is not sure about the meaning of the result.

file that must be used to draw the map". The user crosses the execution gulf but he/she faces an unexpected result during the evaluation gulf, that is, no file is shown. The user does not know if he/she made some mistake because the system does not inform him/her about executing (running) some software routine. The novice user will need some help because he/she will not know what to do. This scenario is described in Table 4.

The need for help characterizes a communication breakdown. The system should advise the user that it is necessary to take some action related to the kind of external file extension (CAD reader, Database Access, and so on) when the file extension is not a "shapefile" (the ArcView file extension). This lack of communication results in a failure at the action support level that interferes with an evaluation of the preview result and fails to assist the user in defining the next user decision.

5. After asking for some help from outside the system, the user redefines his/her aim. The user crosses the execution gulf but at the evaluation gulf moment an unexpected result occurs, that is, nothing is shown on the screen. The difficulty is to know if the file extension is indeed activated since no confirmation message is displayed. Because nothing happened, the user may believe the file extension is selected only by clicking over the file name. But the system

requires the user to click on the checkbox related to the file extension although the user does not yet know it. This scenario is described in Table 5.

Again, the system fails because of the absence of some message that could help the user to evaluate the result of some action taken and what should be done next.

6. The user assumes that the system activates the file extensions and again has the intention of using the "add theme" action. The user crosses the execution gulf however a new element of the process appears in the evaluation gulf and the user tries to identify it. The user does not know how to proceed. This scenario is described in Table 6.

If the system interface environment is not familiar to the user, that is, if he/she is not aware of the purpose of every interface widget he/she is not aware of checkbox functionality. In this situation there is a communicability fault in the system because of the lack of a message that could support the user in deciding what action has to be taken.

7. Considering that the user decides to activate the checkbox, the novice user can finally cross the execution and evaluate gulfs to achieve his/her aim. This situation is described in Table 7.

Table 3: Scenario 3.

Goal		View the map on the screen
Execution	Intention	Add one theme
	Actions specifications	Select the <i>add theme</i> button
	Execution	Click the <i>add theme</i> button on the tool bar
Evaluation	Perception	A dialogbox is shown on screen (<i>Oops!</i>)
	Interpretation	What to do in the dialogbox? (<i>What now?</i>) At this moment a cognitive disconnection causes a breakdown.
	Evaluation	Evaluation is hampered by the ambiguity of the application's response system.

Table 4: Scenario 4.

Goal		View the map on the screen
Execution	Intention	Look in the dialogbox for the file that will show the map
	Actions specifications	Select the file in the computer's directories that will show the map
	Execution	Look in the dialogbox for the file in which the map data are stored and select it
Evaluation	Perception	No file appears (<i>Oops!</i>)
	Interpretation	(<i>What happened?</i>) If the action to be taken was correctly selected, why was the map not drawn on screen? (<i>Why didn't it work?</i>)
	Evaluation	It will be necessary to ask for some help.

4 ACHIEVED RESULTS

For a novice user, the evaluation of the user interface of both systems, ArcView and Spring, resulted in the same kinds of difficulties. The main difficulties are related to the evaluation gulf. A significantly greater number of repeated problems were found in Spring than in ArcView user interface use. Spring also presented a greater number of execution gulfs, mainly related to the necessity of more help for the user, without which the system fails. Table 8 shows a synthesis of the problems identified.

Although Table 8 shows different numbers for each evaluated tool, its intention is not to establish quantitative differences between them, but to summarize all problems found in both of them, well-known and widely used GIS tools, one of them commercial and the other free. It is worth to note that the qualitative information determined by the scenarios evaluation from the semiotic approach is potentially richer as a system communicability design insure than the quantitative results shown in Table 8.

The same example of interface analysis based on scenarios built for an experienced user, who knows which commands he/she has to run on the interface, does not solve all of the interface problems. The experienced user can cross the execution gulfs but, like the novice user, cannot successfully cross the evaluation gulfs because most of the time the user does not know the system state. Then the user experiences the following types of problems:

- Did the chosen command really run? The user does not know if the selected command is being run by

the system or even if it was already run, because in many situations there is no interface change or confirmation message.

- Was the command correctly selected? It is impossible for the user to notice when he/she has chosen a wrong command because there is no confirmation of a command result.
- Is the sequence of chosen commands correct? The user only notices mistakes in the command sequence when he/she finishes the task and does not achieve his/her goal.

ArcView and Spring communicability related to interface quality for those tasks described in this paper are characterized as follows:

Strategic messages were not found. Strategic messages are those messages that help the user to understand the strategic aspects of tool use, that is, messages that show the user a sequence of tasks that can make the system use viable and efficient.

At the level of action specification and evaluation supporting messages, both systems fail repetitively due to the lack of beforehand advise (which occurs more frequently with Spring than ArcView) and for the lack of explicit information about the system's state after an user action. Sometimes communicability breakdowns occur because there are no changes visible on the screen. This situation characterizes an extreme lack of communication in the interface, making it difficult to evaluate the result of any user action.

Both ArcView and Spring present the same kind of operational messages in response to user actions: dialog boxes and checkboxes. The quality of these re-

Table 5: Scenario 5.

Goal		View the map on the screen
Execution	Intention	Activate the ArcView file extensions related to the CAD data file
	Actions specifications	Select the option extensions and the option CAD Reader in the File menu.
	Execution	Select the option extensions in the File menu and activate the ArcView extension related to the CAD reader file in the dialogbox, clicking in its checkbox.
Evaluation	Perception	There is no visible change.
	Interpretation	Is the file extension activated? (<i>Oops!, What happened?</i>)
	Evaluation	The resulting evaluation is degraded by the system inability to communicate with the user.

Table 6: Scenario 6.

Goal		View the map on the screen
Execution	Intention	Add a theme to the CAD data file.
	Actions specifications	Select the <i>add theme</i> command and select the map data file.
	Execution	Click on the <i>add theme</i> command button in the toll bar in order to add a theme; look for the map data file in the dialogbox and select it.
Evaluation	Perception	The map related theme is added to the table of contents in the view panel, next to a checkbox, and nothing is drawn on the screen (<i>What is this?</i>)
	Interpretation	Do I have to select the checkbox? (<i>What now?</i>)
	Evaluation	If the interface tools are familiar to the user, he/she realizes that it is necessary to select the checkbox.

sponses depends on the level of user knowledge about the interface widgets. User knowledge about the system becomes an essential factor in understanding operational messages. Then, a more precise evaluation of system communicability is related to user background. In this work, user system scenarios were built assuming a novice user who could not understand the operational messages. Therefore, dialog box and checkbox messages were not efficient because they were the only messages from the system to the users in response to his/her actions and consequently some cues to future actions.

The operational level of interface communicability also includes interface element labels. Labels proved not to be appropriate for every user interaction situation. The action "add theme" in ArcView is available from the moment a session is opened, but it is only related to the first step of the process of drawing a map and not to the whole process. In Spring, the same action (*draw*) is also available as soon as the session is opened even though there is no information level selected. An appropriate approach to interface design would be to label this action button with some more specific name for the first step of drawing a map. After this first step, the button would be available only when the software is enabled to draw a map.

5 CONCLUSIONS

Both of the systems evaluated are well known for their complexity. The complexity is related not only to the interaction elements present on the interface, but also to the large range of tasks that can be accomplished by these systems. This study focused on a single task and confirmed the general opinion of these applications. A novice user cannot explore them without significant assistance from a more experienced user or by studying books and manuals, while even an experienced user often faces some difficulties.

The problems discovered in those scenarios outlined above for a novice user show us the existence of general systems interaction faults related to the request (execution gulf) and task evaluation (evaluation gulf) processes. This conclusion is based on the repeated breakdowns that occur during a wide range of tool interaction. The regularity of breakdown occurrences allows us to conclude that these interface problems can occur during any system tasks.

The problems we observed related to the evaluated task, that is, to draw a map on the screen, suggest some important problems with system communicability. The information faults at the level of actions request and evaluation occurred more frequently when the user tried a different action to accomplish the same task because the preview action did not work. Most of the time, there is no change on the system screen or any kind of message that could indicate to the user the system state. Consequently he/she can-

Table 7: Scenario 7.

Goal	View the map on the screen	
Execution	Intention	“Drawn the map on the screen”
	Actions specifications	Select the checkbox
	Execution	Activate the checkbox related to the theme of the table of contents that has been just added.
Evaluation	Perception	The theme is shown on screen.
	Interpretation	The drawing on the screen corresponds to the map.
	Evaluation	The task is successfully completed. The search for information is over.

Table 8: Scenario 8.

Cognitive difficulties	Gulf	Kind of breakdown utterances	Breakdowns (ArcView)	Breakdowns (Spring)
Which command to run?	execution	What now?	1	8
Which commands are available?	execution	What is this?	1	1
Which is the command sequence?	execution	Where is it?	1	1
Do I need some help?	execution	Help	0	9
Is the command correctly chosen in order to achieve my goal?	evaluation	Oops!	3	3
What do I do now? Which is the next step?	evaluation	What happened?	2	4
evaluation What now? 2 3 What happened?				
Has the command really executed?	evaluation	Why didn't it?	1	1
Do I need some help?	evaluation	Help	1	1
What is it?	evaluation	What is it?	1	0

not evaluate the results of his/her action. Although experienced users can overcome some of these system faults, they still face some unnecessary difficulties caused by the lack of messages that would confirm the results of action taken.

However, both systems fail more fundamentally at strategic level. They do not possess any kind of advisement to the user about the complexity of the tasks and the best procedures to be carried out in order to complete the tasks. All these problems besides the lack of procedures to make the buttons available and not available in a dynamic way, and the inappropriate button labels, make the use of these systems very difficult for the user under consideration.

As for future research recommendations, we suggest to repeat this study for a larger range of tasks and user system tests in order to validate the current results and complement the scenarios technique.

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