Rating Method for Usability Evaluation of Analogue Tourist Maps Based on Analytical Models

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Abstract

The article discusses the evaluation of usability of analogue tourist maps based on the model. The aim of the paper is to design a model and to use this model for analogue tourist maps usability evaluation. For usability evaluation the modified NGOMSL model that is used in software engineering branch is chosen. This model serves to predict the execution time of the typical commands that end user has to accomplish. Validation of the suggested model was conducted on the base of user testing that was conducted simultaneously.

Keywords: cartography, maps usability, evaluation of usability, NGOMSL

Introduction

All spheres of human life are influenced by the development of information technology. Cartography has not escaped from this trend. Currently, a lot of maps are increasingly implemented in a digital electronic form. Their advantage is the fact that these maps can be accessed online, since most mobile phones or similar devices allow access to the requested maps through the internet. Moreover, they allow you to find paths between desired points and other facilities. Sure, these advantages are attractive for the end users, but despite this, we can say analogue maps are irreplaceable in some situations. Analogue maps are not dependent on the internet connection and an energy source. Therefore, analogue maps can be used in places where other devices would not be functional and for a time that is not limited. Therefore, it is necessary the user can rely on these maps, and during their using the users have not problems. For this reason analogue map should be evaluated from the usability point of view. There are a big amount of methods in software engineering branch that can be used for usability testing. They differ in data source – data sources can be an end user, an expert or a model. One of the methods group used for evaluation of usability is methods based on analytical models. It is necessary to note, that this method group is often neglected. These methods are based on an analysis of an analytical model that is used for usability predicting. By the evaluation of analogue tourist maps usability through analytical modelling can be obtained, inter alia, the time required to perform the specified operations before it is tested in the real word. Achieved results could be used as the idea of how much time you need to perform the operations on the map. An analytical modelling method can also be used to predict problems concerning usability. It seems useful to apply these methods to analogue maps, although at this time these methods are mostly used when developing computer software.

Existing methods of analogue maps evaluation

The main goal of the maps creation is to create high-quality cartographic product to successfully stand up to use maps in a practice. In order to achieve this goal, various evaluation methods are used for map products. The using of a concrete method depends on the way they were created and depends on the

purpose of conducted examination (Veverka and Zimová, 2008 or Voženílek and Kaňok, 2011). The main objective of maps evaluation according to Čapek (1992) is to accomplish the optimal level of theirs properties, quality and fitness for a particular purpose. Firstly, it is necessary to define a hierarchy of quality indicators for map products, which are evaluated. The main requirements can be defined by a various ways. According to Veverka and Zimová (2008) it can be classified as priority a geometrical precision of a map, which is used for surveying purposes. Another priority may be map's detail. A map should be also explanatory, especially if it is a map designed for orientation in the field.

Usability and its evaluation

There exist a lot of definitions of the usability concept and usability evaluation. According to Nielsen and Mack (1994), the term usability evaluation is usually used for a set of methods based on experiments with participants that have to check or verify the usability aspects in a way to satisfy all the needs and requirements of really end users. Definition according to Steve Krug says that "the usability really means making sure that something works well and that the average person (or even mediocre) with the common capabilities and experience could use some thing (whether it's a website, a combat fighter or rotary doors) for its intended purpose without becoming hopelessly frustrated" (Tullis and Albet, 2008). All the other definitions of usability have similar sense including a user experience with a product, system or other things (Tullis and Albet, 2008). The usability of information systems supports management of business processes in company. According to Šimonová (2012) management of business processes significantly helps to fulfil business goals.

It discloses a large number of methods for usability evaluation. For example, these methods can be distinguished according to the data source, which is used for usability evaluation. These methods include (Nielsen, 1993 or Scholtz, 2014) methods based on user usability testing, usability evaluation methods involving experts' opinions in usability evaluation and usability evaluation methods based on analytical models.

Existing usability evaluation methods based on models

Usability evaluation methods based on analytical models are based on the creation of an analytical model, which is used for predicting of usability of a user interface before usability testing with real end users is conducted. These methods of usability evaluation are not too much paid attention.

Among the best-known method based on analytical models we can note (Ivory, 2014):

- GOMS analysis (Goals, Operators, Methods, and Selection rules), which predicts the execution time and learning time,
- Knowledge Analysis, which deals with the prediction of aptitude,
- Design Analysis, which assesses the complexity of the design,
- UIDE analysis (User Interface Design Environment), is based on an analysis of GOMS within UIDE,
- Cognitive Task Analysis, its main essence is the anticipation of problems with usability,
- Task-Environment Analysis, assesses the mapping of user tasks goals in the user interface.

As it was said, the analytical modelling is a set of methods that are used to predict usability of user interface. Feedback of this forecast can be used in the design stage for selecting from various alternatives and in system performance assessment.

Unlike other evaluation methods the analytical modelling is less expensive and it requires less time. The disadvantage of these methods is less reliable in opposite with methods that use real end users (Ivory, 2014). Within analytical modelling mathematical or logical relationships describing how the system works are used. Analytical modelling methods also can be classified according to whether they support

automation or not. Group of automated analytical modelling techniques includes the GOMS analysis UIDE analysis, cognitive tasks analysis, programmable user models. Group of non-automated analytical modelling techniques includes task environment analysis, knowledge and design analysis (Ivory, 2014). According to the purpose of the modelling methods these methods can be divided into four groups (De Haan et al, 1991):

- task environment analysis models – these methods are based on the modelling focused on the characteristics that lead to the goals of the user within the user interface. Between these models we can include Task Internal External-Mapping,
- user knowledge analysis models – analysis and representation of knowledge that are used in the user interface. This group includes Action Language grammar and Task-Action Grammar,
- user performance models – these methods focus on user behavior and analyze, describe and predict a time to complete the task. The user performance models are GOMS analysis, Cognitive Task Analysis and User Programmable Models,
- user interface models – the aim of these models is to provide to users full privileges in the use of the virtual machine and the ability to present the user interface in multiple levels of abstraction. Between these models are Command Language Grammar and Extended Task-Action Grammar.

GOMS model

Goals, Operators, Methods, and Selection rules model (GOMS in short) is used to analyze the knowledge leading to the successful completion of the task, because it focuses on the user experience. We analyzed the goals indicating the intention of the user. Furthermore, operators towards achieving the objectives, methods consisting of sequences of operators, leading to the completion of the intention and selection rules for selecting an appropriate method for ensuring the achievement of the objectives (Oyewole and Haight, 2010). GOMS model is used to predict the time that is necessary to perform a task and learning through automation. The automation focuses on performance and enables a quantitative analysis, which is not too difficult to automate. This model is included among the analytical modelling methods based on a model of human processor (Model Human Processor model), which is very effective at problems related to usability predicting. GOMS model is ranked among analytic modelling approaches. These are mostly used even if it is used by only one user model requires a clear definition of tasks. (Ivory, 2014 or Oyewole and Haight, 2010) GOMS models can be based on the type divided by Oyewole and Haight (2010) as follows:

Keystroke-Level Model (KLM) is considered one of the simplest models, which is used to predict the soundness and time for expert performance.

Card, Moran and Newell GOMS (CMN-GOMS) is the original formulation of GOMS-based architecture including goal, operators, methods and selection rules. Tasks can be entered here in pseudocode, which leads to subsequent adjustments to avoid syntax. CMN GOMS method can be used as supporting material in formulating the selection rules.

Natural GOMS Language (NGOMSL) is formed by a simple structure of GOMS rules so that it is not too difficult for the user and it also achieves the desired performance and the flexibility of the corresponding standard traditional technique GOMS. Among the advantages of the NGOMSL method we can note an estimate of operating time and the time needed to learn the system.

Cognitive Perceptual Model GOMS (CPM-GOMS) is used in case of division of roles on perceptual or motoric level. The tasks are arranged in a row and unlike other models it can detect overlapping tasks that are performed simultaneously and thus reduce the estimated time of completion.

GOMS model can be according to De Haan et al (1991) used e. g. for modifying of the text user interface, where the goals are defined by a task at different levels. Firstly, general objective formed of several sub-objectives is set. Sub-objectives can be regarded as commands of the computer system which are further divided. At the moment when operators or basic perceptual, motoric, or cognitive task can be used for their solving, partition is broken down at the end. The level, in which the operators are defined, is necessary for the prediction of time to perform the task. It is obtained by adding the times for which they are executed elementary operations of a model. These can include pressing or making of a selection.

Case study

The main goal of the maps creation is to create high-quality cartographic product to successfully stand up to use maps in a practice. In order to achieve this goal, various evaluation methods are used for map products. The using of a concrete method depends on the way they were created and depends on the purpose of conducted examination (Veverka and Zimová, 2008 or Voženílek and Kaňok, 2011). The main objective of maps evaluation according to Čapek (1992) is to accomplish the optimal level of theirs properties, quality and fitness for a particular purpose. Firstly, it is necessary to define a hierarchy of quality indicators for map products, which are evaluated. The main requirements can be defined by a various ways. According to Veverka and Zimová (2008) it can be classified as priority a geometrical precision of a map, which is used for surveying purposes. Another priority may be map's detail. A map should be also explanatory, especially if it is a map designed for orientation in the field.

Goal of evaluation

The aim of the evaluation of usability based on the model is the prediction of necessary time to complete the various tasks performed when working with analogue tourist map (Ivory, 2014, Oyewole and Haight, 2010).

Subject of evaluation

Subject of evaluation are operations done on analogue tourist map that are made on the basis of firmly defined steps. Tourist maps are among the most exploited maps used by a public. By the help of the designed model it is possible to determine the time which is necessary for completion of the operations while working with the map.

Subject of testing

There are a large number of maps, which can be classified on the base of various aspects. The article title refers to the fact that as the subject of testing analogue tourist maps were selected. They have a medium scale ranging up to 1 : 50 000. The tested maps are analogue in its nature. It is a form of recording reality in the form of the classic "paper" maps. Tourist maps were chosen for testing because they are thought to be among one of the most popular maps. In such maps, it is necessary quality design, which has predictive value whether a given user will be willing to use the map or not.

For testing comparable products that meet certain criteria - similar to the display area, scale, year of publication, map orientation, etc., were chosen. Concretely, for testing three tourists analogue maps from leading publishers of cartographic products in the Czech Republic. Geodésie On Line, spol. s r. o. in scale 1 : 25 000, Klub českých turistů 1 : 50 000 and SHOCart s. r. o. 1 : 40 000 were chosen. Tested tourist maps show the area Ralská pahorkatina (Ralsko Upland). All selected maps mainly consist of the same territory and are the up to date (issued at the latest in 2011).

Choosing an appropriate model

The subjects of evaluation are analogue tourist maps. These maps are important for how long a user is able to search assignments tasks on a map. For this reason, it is essential to choose the method that focuses on the analysis of completion time. Among the methods belonging to this group GOMS analysis, cognitive tasks analysis and programmable user model belong. These methods fall into the category of user performance models that focus on the behavior of the user and for completing the task (Ivory, 2014).

After detailed examination of these methods GOMS analysis (specifically NGOMSL model) was chosen. This model predicts predict the time required to perform the task completion. NGOMSL model is based on a simple structure of GOMS rules, which is not too complicated for the user. This model was chosen primarily because it is among the most accepted analytical methods to create the model that corresponds to the desired structure of tasks (Oyewole and Haight, 2010).

NGOMSL model design

NGOMSL model is based on a detailed breakdown of the top-level goals on methods and operators. Their fulfilment leads to successful goal achievement. The methods consist of the steps, which are arranged in ascending order below. Each method can take a different number of steps. Individual steps include operators, which are assigned a fixed amount of time. NGOMSL model is thus composed of top-level goals, methods and steps with operators. These items are referred to as commands. Their total number is used in calculating the time NGOMSL commands. (Lee and Koubek, 2011)

Procedure for construction of a NGOMSL model (Lee and Koubek, 2011)

- choose the highest level of user goals and methods,
- perform the following recursive procedure - suggest methods to achieve each goal, check the consistency and move to a lower level of analysis,
- check decisions and assumptions,
- to complete the analysis.

Firstly, when constructing a NGOMSL model it was established 13 goals at the highest levels (e.g. Unpacking maps and preparation for a work, orientation in a map list, locate the desired targets etc.). Subsequently methods to achieve individual goals, which are composed of different steps, were designed. In these steps, it appears a total of 18 operators that are listed in the following table (see Table 1).

Table 1. Operators used in methods defined to achieve goals

Operator	Description
Unpack	Unpacking of a map product from the cover.
Unfold	Map product layout.
Verify	Verification that the previous steps were performed properly.
Identify	Identify the item on the map product.
Locate	Find the village on the map.
Indicate	Mark the position of the water surface.
Show	Point to a river flowing through the municipality.
Speak	Say the name of the specified object.
Find	Locate the symbol of the object in the legend.
Set	Determine the location of the object.
Allocate	Define the railway route, which is located between two points.
Define	Define colour tint of hiking paths between two points.
Learn	Find out which shortest hiking trail is located between two points.
Calculate	Calculate the length of specified route in km.
Look at	Find out where on the map geographic coordinates are located.

Express	Express latitude or the length of the site.
Tell	Tell altitude, which is determined by the object.
Estimate	Estimate the distance between two points in km.

Furthermore, all decisions and assumptions relating to individual targets were checked. For this purpose the operator "verify" that is part of each objective was used. Finally, an analysis revealing completion objectives was conducted. Part of the NGOMSL model is shown in the following figure (see Fig 1).

NGOMSL commands

Method: Unpacking map and its preparation for full-fledged work
Step 1. **Unpack** the map from the pack
Step 2. **Unfold** the map and have it ready for full-fledged work
Step 3. **Verify** that the map is ready for full-fledged work
Step 4. Report on goals completion

Method: Orientation in the map list
Step 1. **Identify** the map name
Step 2. **Identify** the numerical scale
Step 3. **Identify** the graphic scale
Step 4. **Identify** the legend
Step 5. **Identify** the overview map
Step 6. **Identify** the year of map publication
Step 7. **Verify** that items mapping product designed correctly
Step 8. Report on goals completion

Fig 1. Part of the NGOMSL model

Time defining in NGOMSL model

Usability evaluation based on the model is generally used mainly in the software development. Definition of basic operators' times in this case according to Card et al (1983) is determined on the basis of exact measurements. For example, the defined value of 0.28 for the keypress, 0.1 to press and release the mouse button, 1.1 for mouse movement etc. (Card et al, 1983). To use the NGOMSL model for analogue map have not been set times basic operators yet. Based on literature the most accurate values are got by an empirical investigation. In this study two methods were tested. Firstly, the times were determined on the basis of a questionnaire and secondly the method of determining the base times of the operators based on the exact measurements was conducted. With help of this method exact time at which participants performed various subtasks was measured.

Survey

To establish the times of operators, a survey was conducted. This research was attended by 104 respondents. The group of respondents was composed of 96 students from the Faculty of Economics and Administration, University of Pardubice, 6 participants who were involved in user testing and two employees of the University of Pardubice. The questionnaire was created through Google Forms and was composed of 25 questions, with 23 questions about working with maps, where respondents estimated duration of the task (in seconds). Before beginning the questionnaire they were shown a paper map to be familiar with the various tasks related to the work with a map that displays unfamiliar territory with unknown villages, rivers and other sought after features.

Calculation of times necessary to complete the task in NGOMSL model
From a statistical set, which was obtained by the questionnaire survey, they were determined individual values operators. These operators were determined as the average of all values of a given operator. The resulting operators times are given in the following table (see Table 2).

Table 2: Operators times established on the basis of survey

Operator	Time [s]
Unpack	6.88
Unfold	16.13
Verify	12.35
Identify	12.78
Locate	32.43
Indicate	16.33
Show	16.10
Speak	5.26
Find	17.21
Set	26.56
Allocate	34.24
Define	19.55
Learn	41.93
Calculate	71.55
Look at	33.56
Express	49.09
Tell	56.90
Estimate	47.53

After determining of individual operator times it is possible to calculate the time that is necessary to accomplish each task and the total execution time. Time of execution of all commands in the created model, according to Helander (1988) is determined by the following formula:

Execution time = NGOMSL command time + Basic operators time + Time of mental operators + System response time

where:
- NGOMSL command time – number of NGOMSL commands multiplied by the 0.1 sec,
- Basic operators time – the sum of basic operators,
- Time of mental operators – the sum of mental operators defined by an analyst,
- System response time – total time of user inactivity.

Substituting the appropriate values into the formula above, it was found that the time necessary to perform the operations carried out on the analogue map that are listed in the scenario, is 26 minutes. The values of operators set by questionnaire are overvalued. This is probably due to a distorted idea of the duration of the various activities carried out on the map, because here the respondents stated values based on estimates rather than experience.

Exact measurement
Because previous questionnaire survey set values of operators that have been greatly overestimated, and therefore did not give an optimal result, it was used precise measurements to determine the times of operators. Accurate measurement of the times of different activities was conducted in an experiment when 6 participants worked with the analogue maps. The participants performed the same tasks that were itemized in detail and assigned to them relevant operators. Time of the task in this case includes several times, which were measured separately. Each participant performed the task using three scenarios and three different map products. Using this principle it was obtained 18 measurements used to calculate the times of individual operators.

Calculation times needed to complete the task model NGOMSL
From the values obtained from measurements the values of operators were determined. They were, as in the case of a questionnaire survey, determined as the average value of all the values appropriate to that operator. The resulting time operators are given in the following table (see Table 3).

Table 3: Operators' times set by measuring

Operator	Time [s]
Unpack	1.95
Unfold	14.07
Verify	3.50
Identify	5.65
Locate	12.70
Indicate	13.83
Show	3.56
Speak	4.59
Find	14.91
Set	14.72
Allocate	16.68
Define	12.59
Learn	7.76
Calculate	26.07
Look at	3.59
Express	18.16
Tell	18.02
Estimate	20.03

After the exact times of individual operators determining it is possible to calculate the execution time, which is necessary to execute all commands listed in the NGOMSL model. This calculation is made based on the formula above. After performing this operation, it is found that the time necessary to perform the specified tasks on the map by an exact measurement is 12 minutes.

Model evaluation

The evaluation of the model was carried out by comparing the time necessary to execute commands contained in the NGOMSL model and using the above procedures. Firstly operators' times were compared to the time obtained by questionnaire survey and the exact measurements. They are listed in the following diagram (see Fig 2)

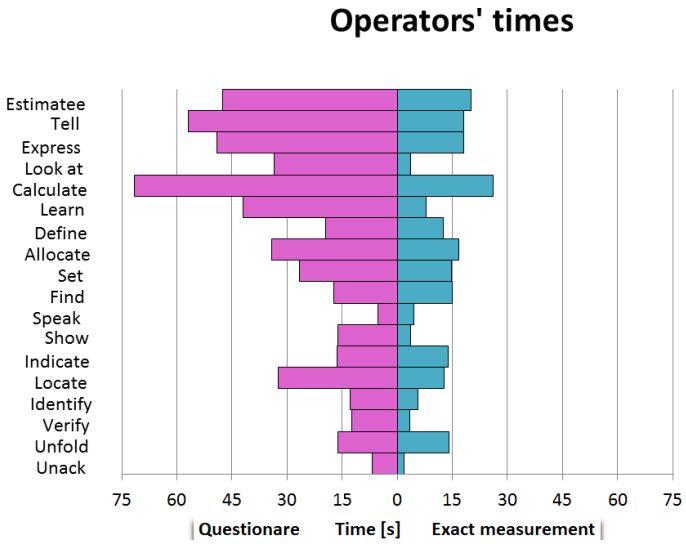

Fig 2. Operators' times set by both methods

The figure above shows that almost all operators' times obtained by exact measurements are several times smaller in comparison with the times obtained from questionnaires. This is due to the vagueness of questions in the survey. Respondents estimated value without trying of tasks and their idea about the real duration of individual operations was greatly distorted. It negatively affected the times of individual operators.

Make it clear whether it has achieved the fair values of the times necessary to complete the task by questionnaires or by exact measurements, these two methods were compared with the durations of individual tasks identified by the realized user testing. This testing was performed with six participants in a simple test room. Some tasks times identified by questionnaires much higher in comparison with values measured by user testing. Especially the operators: locate, delimit, determine, estimate, express, define and calculate.

Times detected by exact measurement and by a user testing give similar results. Based on the comparison above, we can say that it is preferable to determine the times of operators by using of exact measurement method. This method gives minimal deviation of values in comparison with user testing method.

Conclusion

Each product and service must meet certain parameters, which ensure user satisfaction in their use. For this purpose, manufacturers or service providers has to validate their usability, which is carried out in interaction with the user. In the case of analogue maps it can be tested usability to identify the usability undesirable problems encountered in working with the map or estimation of time that a user must spend working with the map. Elimination of usability problems is very important as it desired product becomes easy to use product that meets the needs of users.

The aim of the artic it was to design and to validate usability testing and evaluation based on analytical mode and to validate this model in a case study when three analogue maps are evaluated by this model. For evaluating of the usability the NGOMSL model was chosen. This model serves to predict the time of execution of all commands contained in the model.

The method of user testing was performed on three analogue tourist maps from leading publishers of cartographic products in the Czech Republic: Geodézie On Line, spol. s r. o. 1 : 25 000, Klub českých turistů in a scale of 1 : 50 000 and SHOCart s. r. o. in scale 1 : 40 000. These products show the same area and have similar characteristics.

For the chosen model it was conducted setting of operators' times by two methods. Firstly they were determined on the base of the survey, which was attended by 104 respondents. These were mainly students of the Faculty of Economics and Administration, University of Pardubice. This method proved to be an unsuitable. Times of individual operators were overvalued. For this reason, a different method was used for determination of operators' times, which is based on exact measurements. There was measured the exact time at which participants performed various subtasks. Measurements were performed on six participants; each participant performed the task using three scenarios and three different map products. Using this principle was obtained 18 measurements used to calculate the times of individual operators.

As the benefit of the article it can be considered successful application of analytical modelling for analogue maps, since this method has been mainly used in computer software so far.

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