Fuzzy usability evaluation of Information systems in Public administration

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Abstract: This paper deals with the problem of evaluating a usability of information systems in public administration based on a theory of fuzzy sets. For such purpose, a completely new methodology has been created. The evaluation of the model is based on a set of criteria that synthesizes commonly used Web usability guidelines. Together with the model, Fuzzy Usability Evaluator – the application that is able to operate with the vague nature of evaluating has been developed. While the inputs are fuzzy measures, the output of the model is a crisp value representing an overall usability score of the Web portals in Public administration.

Key-Words: Usability, information systems, public administration, fuzzy logic, methodology, software quality

1 Introduction
A usability becomes extraordinary important in today’s information age. The discipline dealing with it - usability engineering is quite new in terms of history, experience and number of trained people. Yet, it became very popular.

An importance of usability evaluation increased rapidly in last 10 years [11]. In contrast to the past, users are no longer forced to use particular product that does not fully satisfy their needs or requirements, just because there does not exist any other. That is also why the measuring of usability had been underestimated.

At present, the usability is a fundamental part of software engineering [12]. It can reveal qualities of product as well as lack of functionality, which usually arises during the design phase of a product. Moreover, the usability testing is not only limited to testing the quality of use of software products, it can test almost any kind of product that has an user interface such as remote controller as well as a cell phone [6].

2 Problem Formulation
Although usability studies are widespread, the issue of Web sites usability evaluation remains still a very young and unexplored area of interest. There is not any clear consensus how to measure usability obtaining a significant score for the Web site usability, taking also in mind that users’ language is full of vague expressions, ambiguities and uncertainty [13].

Measuring the usability results from a need to have:
- an objective indicator of quality of use,
- a value that can be compared to the other similar values.

2.1 The Goal of the Research
The goal of this work is to create a methodology easing the user’s ability to evaluate the usability by using his natural language, which is full of vague expressions. Since it is not appropriate to express vagueness, uncertainty or ambiguity (as natural parts of communication, decision making and other common processes that human beings are surrounded and interact with) using classical binary logic, this work presents a completely new approach for usability evaluation based on fuzzy logic.

The model will be based on a set of Web usability guidelines, which is going to be selected thoroughly and sensitively according to the characteristics of the target environment. The output of the model should be a single real number representing the overall score of particular Web site. This score could be used either as a measure of usability as a part of overall quality or as well as an input for comparative analysis.

The proposed methodology is going to be developed for Web sites of Public administration (WSPAs), but it is not only limited to them, if the input criteria will be modified according to the characteristics of different environment.

2.2 Problem Decomposition
In order to achieve the goal proposed in this paper, a problem definition should be first analyzed.

The initial problem is to perform a “usability evaluation of Information systems in Public administration using fuzzy logic”. Apparently, such definition seems to be complicated at first sight. Hence,
it is appropriate to decompose it. The proposed initial problem decomposition is presented in Table 1.

Table 1: Initial problem decomposition

<table>
<thead>
<tr>
<th>Notation of decomposed part</th>
<th>Auxiliary question</th>
<th>Decomposed part</th>
<th>Area of interest</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject / task</td>
<td>What task is about to be performed?</td>
<td>“Usability evaluation”</td>
<td>Usability engineering</td>
<td>Usability testing, questionnaires</td>
</tr>
<tr>
<td>Object</td>
<td>On what object is to be the task performed?</td>
<td>“of Information systems”</td>
<td>Information systems</td>
<td>Structure of the Information system</td>
</tr>
<tr>
<td>Environment</td>
<td>In what environment will be the task performed?</td>
<td>“in Public administration”</td>
<td>Public administration</td>
<td>Characteristics of the environment, its users and relationships of the system</td>
</tr>
<tr>
<td>Methodology</td>
<td>By the help of which method, is the task going to be performed?</td>
<td>“using fuzzy logic”</td>
<td>Fuzzy sets and systems</td>
<td>Operations with fuzzy sets, fuzzy numbers, fuzzy inference system, fuzzy rule base</td>
</tr>
</tbody>
</table>

According to the presented decomposition, the problem should be first defined per parts, described individually, then synthesized and solved as a complex problematic.

2.3 Web site Usability Evaluation

Measuring the usability aspects of the system’s user interface with the help of particular methodologies is called the usability evaluation [2], [12]. As stated in [5], the usability evaluation can reveal the problems of the design and allows also better understanding of the targeted users [12]. According to [14]:

“The usability is measured by how easily and how effectively it can be used by a specific set of users, given particular kinds of support, to carry out a defined set of tasks, in a defined set of environment”

Literature [12] recommends measuring usability by having a number of test users, selected to being as representative as possible, who performs a set of tasks on tested system.

Testing aspects of Web site’s usability is in fact the same as a testing of any another interface. Web site usability evaluation differs from general usability testing of some software product by different set of guidelines, tasks and possibly also by a broader spectrum of users of such system. Therefore, a Web site usability definition is very similar (if not the same) to the one presented above.

Guidelines list well-known principles for UI design, which should be followed in the development project [12]. Various usability guidelines exist and have been established by different authors. These can be found for instance in [15], [11], [5], [9]. Each of them focuses on how to satisfy users by presenting usable Web design. However, there is no general agreement about which Web guidelines are correct. Additionally, contradictions exist among guidelines [5], which might be caused by many factors, for instance as follows:

- specifics of particular Web environment,
- changes in the technology,
- relative propriety only for a specific group of users, etc.

There are many Web design recommendations, which provide Web developers with useful usability guidelines. Following list contains several commonly used and empirically validated Web usability guidelines. Each of them affects one of the aspects of Web site quality such as readability, understanding the navigation, understanding the content, Web design quality, recency, etc.)

- The content should represent 50 - 80% of the page [11].
- Update content often [4], [11].
- Too many colors in the design reduce their functionality, which affects the readability [1].
- Minimizing the use of the users’ memory is one of the major usability recommendations [11].
- The font size has a major influence on the legibility of Web page [8].
- The number of images in the Web pages should be minimized unless they are necessary [11].
- Minimize animated graphics, which could negatively affect the readability [4].
- Download speed should be no more than 10 seconds [11].
- Use consistent navigation elements [4].

2.4 Environment of the Public Administration Information Systems

Constraining the problematic to the environment of Public administration will ease the complexity of the initial problem; a set of affecting factors – specific input variables, will be chosen in order to retain all characteristic aspects and to develop a realistic model of such environment.

Public administration (i.e. state administration and local authorities) can be broadly described as the development, implementation and study of branches of government policy [15]. It is linked to pursuing public good by enhancing civil society and social justice. Public administration in contrary to the state administration has a decentralized, local character.

Among many other responsibilities, a local authority usually administrates its Web site where various kind of information is presented.
2.4.1 Information Systems in Public administration

Various systems can be considered as Information systems in Public administration (ISPA). It is evident, that there exist also information systems focusing on other areas of interest; for instance corporate, transportation, educational, mobile, family, industrial, chemical etc.

An Information system (IS) is according to [16] the system of people, data and activities that processes the data and information in a given organization, including manual processes or automated processes. Usually the term is used as a synonym for computer-based information systems, which is only the Information technologies component of an Information system.

A definition coming from [19] defines ISPAs as a set of ISs that serve the execution of Public administration and support its activities. ISPAs should also provide public information services.

2.4.2 Web Portal of Public administration (WPPA)

Since the common definition of IS presented above does not particularly determine any particular framework, the one that is accessible with minimal restrictions for maximum users should be chosen. Such platform can be easily evaluated, tested; the selected group of tested subjects would be highly representative.

Authors assume to use the Web-based ISPAs, since the Web platform is recently the most dynamical environment for presenting any kind of information.

A Web portal is a site that functions as a point of access to information on the World Wide Web (WWW). Portals present information from diverse sources in a unified way. Aside from the search engine standard, Web portals offer other services such as e-mail, news and other features [18]. A WPPA could be perceived as a virtual environment in which citizens meet the Public administration, where portal represents one initial point, which allows access to services and information provided by Public administration [10] (see Fig. 1).

2.5 Fuzzy logic

As cited by [16], classes of objects of the real world do not have precisely defined criteria of membership. Such classes, however imprecisely defined, play an important role in human thinking [16].

Fuzzy variables are more attuned to reality than crisp variables [7]. In fact, it is a paradox that data based on fuzzy variables provide more accurate evidence about real phenomena than those based upon crisp variables.

High levels of uncertainty (e.g., “She might be married, but perhaps she is divorced”), imprecision (we might report a length as 2m when it is actually 2.324 m), ambiguity (e.g., “He is tall”), vagueness, fuzziness and complexity of real-world problems lead to recognition that classical dichotomy logic is not sufficient for solving such problems. Ways of expressing uncertainties according to [13] include theory of probability, fuzzy logic, Bayes’ theorem and Dempster-Shafer theory. He also remarks that each theory has its advantages, disadvantages and problems. Although any convincing argument cannot be presented, he finds fuzzy system theory as the most suitable to deal with uncertainty, ambiguities and contradictions, having as the only presented theory a clean mathematical framework provided by fuzzy sets. However, for many scientific fields, the fuzzy logic is the only suitable apparatus, while the other theories fail.

Fig. 1: Web portal functioning

The most suitable type of Information system to perform the proposed goal will be the Web portals presenting the municipalities (generally local authorities): cities, small towns, villages, districts or any other Web sites that presents some urban area or municipal territory, which also falls within Public administration.

The reasons leading authors to choose this particular type of IS are following:

- it has large number of users due to its accessibility,
- it is not subject to any restrictions of use,
- it is free of charge,
- to understand its content does not require any special knowledge,
- the representative group of typical users can be easily chosen,
- it is constantly available,
- testing its usability has a utility, which can result in increasing the quality, if the results of evaluating reveal any problems,
- the results of evaluation can be compared to other similar Web sites.

When the function takes any real value between zero and one, it indicates partial degrees of membership of the element x into the set \( \tilde{A} \). This generalized characteristic function is known as membership function \( \mu_{\tilde{A}} \) defined by (1) as:

\[
\mu_{\tilde{A}} : X \rightarrow [0, 1] \quad \text{where} \quad x \in X \quad (1)
\]

The membership is defined over the closed interval \([0, 1]\) and since it can be partial, the set is known as fuzzy set \( \tilde{A} \), while the notation \( \mu_{\tilde{A}}(x) \) indicates the membership of the element x into the fuzzy set \( \tilde{A} \). Thus, the fuzzy set \( \tilde{A} \) might be represented as (2):

\[
\tilde{A} = \left\{ \left( x, \mu_{\tilde{A}}(x) \right) | x \in X \right\} \quad (2)
\]

The basic concept which makes possible to treat fuzziness in a quantitative manner is based on a membership function [17]. Each membership function defines a fuzzy set and receives a linguistic label (name) that assigns the linguistic value to the set.

The membership functions may be of almost any shape, very often they are triangular (piecewise linear), s-shape (piecewise quadratic) or normal (bell-shaped). They may also be trapezoidal with an interval within which the membership is equal to 1.

The variable described by fuzzy sets and defined over specific context-dependent universe of discourse is known as linguistic variable. Linguistic variables are discrete fuzzy sets. They consist of the name of the discrete fuzzy set (e.g., speed), the names of its members – linguistic values (or linguistic terms), and for each linguistic value, a membership function exists [13].

For example, a variable such as speed, defined in the context of a car, has universe of discourse between 0 kilometers per hour and 220 kilometers per hour. Such linguistic variable “speed of the car”, can be divided into three fuzzy sets (granules\(^1\)), whose linguistic values are “low speed”, “medium speed” and “high speed”.

As discussed above, fuzzy sets are helpful to describe vague concepts, since they do not possess sharply defined boundaries [17]. It is very important to point out, that the representation of the concepts in terms of a membership function depends not only on the concept itself, but also on the context of the idea. For example, the idea of “high speed” can be interpreted in several contexts. The driver of the car may consider the speed of 180 kilometers per hour as “high speed”, while the pilot of the racecar considers “high speed” somewhere around 300 kilometers per hour. Thus, the concept of “high speed” would be defined with different membership functions for each concept.

Fuzzy controllers in contrary to classical controllers are capable of utilizing knowledge elicited from human operators [7]. Since it is also very difficult to express such knowledge in precise terms, an imprecise linguistic description of the control problem can be used instead. This linguistic description consists of a set of control rules that inheres in the knowledge base.

A general fuzzy controller as stated in [7] consists of the following elements:

- fuzzy rule base (knowledge base),
- fuzzy inference engine,
- fuzzification module,
- defuzzification module.

In general, fuzzy controllers are special expert systems\(^2\) [7]. The range of control problems vary from complex tasks to simple goals as maintaining a prescribed state of a single variable [7].

The process of drawing conclusions from existing data is called inference; new truths are inferred from old ones [13].

The purpose of the inference engine is to combine measurements of input variables with relevant fuzzy rules in order to make inferences regarding the output variables. The given fuzzy inference rules are used in the form such as (3)

\[
\text{if (this is true) then (do that)}. \quad (3)
\]

A typical example of a fuzzy control rule is (4)

\[
\text{IF speed is very high AND torque is high THEN gear ratio is very small}. \quad (4)
\]

A fuzzy controller operates by repeating a cycle of the actions as that one shown on Fig. 2. For instance, [7] defines the process of inference as follows. First, measurements are taken (e.g., the facts are evaluated, the simulation is executed, etc.) of all variables that represent the process. Next, these measurements are converted into appropriate fuzzy sets to express measurement uncertainties (see Step 1 on Fig. 2). This step is called a fuzzification. The fuzzified measurements are then used by the inference engine to evaluate the control rules stored in the fuzzy rule base (see Step 2 on Fig. 2). The result of this evaluation is a fuzzy set (or several fuzzy sets) defined on the universe of possible actions (see Step 3 on Fig. 2). This fuzzy set is then aggregated (see Step 4 on Fig. 2). In the final step of the cycle the aggregated set is converted into a crisp value that is in some sense the best approximation of such fuzzy set. This conversion is called a

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\(^1\) Granularity represents number of membership functions [7]

\(^2\) Expert systems are computer programs, designed to make available some of the skills of an expert to non-experts [13].
defuzzification (see Step 5 on Fig. 2). The defuzzified values represent actions taken by the fuzzy controller in individual control cycles [7].

Fig. 2: The process of fuzzy inference with fuzzified input measurements

3 Problem Solution

According to facts mentioned above, there is a need to create usable and reasonably accurate methodology helping to evaluate Web site’s usability representing several of commonly acknowledged Web site usability guidelines.

The results of background research helped to gain the idea how to solve the initial problem. As stated previously, the definition of the initial problem itself is very difficult, therefore the problem was decomposed and its parts were described separately. Authors suppose that the coherence between usability and fuzzy theory is the most difficult objective, since there is no scientific background or research studies regarding this approach for measuring the usability.

An own set of suitable criteria (based on commonly accepted guidelines for Web usability) will be chosen. Such set however small might seem, retains all major characteristics of target environment and approximates the result of usability evaluation accurately. It is necessary to remark, that no standard usability score scale have been created. Authors are not trying to create any kind of standard scale, but rather to experiment with the results of this interesting and promising area of interest.

Rather than performing a complicated general analysis, there is a need to create a realistic model solving the problem and an interactive application, so this can be put in operation and used repeatedly without expert knowledge of the fuzzy theory. Fuzzy theory is a powerful apparatus helping to manage the uncertainties, but very truly, its advanced techniques are very difficult to understand, especially for people who are only interested in finding the more suitable way how to evaluate the usability of the Web sites. Thus, the entire fuzzy inference engine should be hidden, not visible for those who does not need or want to deal with it.

Commonly known working environment should be used. Such environment must offer both simple and advanced operations, as well as a graphical user interface (GUI), graphical outputs, and simple database. Microsoft Excel was chosen as a fully convenient environment for the purpose of this research. The results can be easily interpreted in graphical form or in form of summaries. Furthermore, Microsoft Excel allows structuring the information transparently. Sure, in future the special adjusted software can be developed, but the aim of this research is to verify hypothesis the fuzzy logic can be used for usability evaluation.

For the purposes of this work an application Fuzzy Usability Evaluator (FUE) has been developed. FUE is a WPPA usability evaluator using fuzzy logic. With FUE, one can:

- evaluate the usability,
- collect the results of usability testing,
- use the results to get the score for evaluated Web site,
- extend the rule base,
- extend other knowledge obtained by testing,
- use own set of characteristics (input variables) for use in different environment,
- display the outputs in graphical way,
- work in advanced mode to get detailed results.

FUE is an analytical application consisting of multiple collaborating modules providing a good visual and computation feedback to a person controlling it – the evaluator. FUE is a lightweight application that does not require highly educated or experienced operator trained for particular environment (such as MATLAB, Simulink, etc.). There is large potential making FUE very scalable, customizable tool for evaluating the usability of particular environment. FUE can be considered as an expert system, since it consists of the powerful computation engine, several databases containing expert knowledge giving FUE new possibilities how to deal with uncertainty, vagueness. FUE requires less from target users while it offers a lot to the evaluators.

The reason FUE was created, was the lack of transparency, ease of use, usability of powerful all-in-one tools such as MATLAB.

FUE consists of several modules; each of them has a different function. In current version of FUE, there are nine modules:

- Overview
- Questionnaire
- Detailed questionnaire
- Evaluation

4 Conclusion
The solution how to deal with the initial problem Fuzzy Usability Evaluator, groups the methodology necessary for evaluating the usability of the WPPAs. FUE is not a usability validator on first place, detecting the deviations from usability standards (guidelines), but rather an evaluator, providing the information about quality of use of the Web site.

In the future, we shall continue in this research, presenting more facts about the proposed methodology as well as demonstrating the features of Fuzzy Usability Evaluator.

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