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Using the Choquet Integral to Improve Systems Usability: A multicriteria analysis

Luiz Flavio Autran Monteiro Gomes[a], Maria Augusta Soares Machado[a], Luís Alberto Duncan Rangel[b] , Renato Monte Araujo[a]

[a]Ibmec/RJ, Av. Presidente Wilson, 118, 11th floor, 20030-020, Rio de Janeiro, RJ, Brazil, Phone: +55 21 45034053, E-mails: (autran, mmachado)@ibmecrj.br

[b]EEIMVR/UFF, Av. Dos Trabalhadores, 420, Volta Redonda, RJ, Brazil, duncan@metal.eeimvr.uff.br

Our problem: A growing Brazilian university with 15,000 graduate and undergraduate students and 3 campuses in different cities wanted to improve its intranet system from the point of view of usability to the students

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Our research question: Given six basic metrics for measuring the usability of a system, how to identify the most important constructs that are associated to each one of those metrics?

The set of metrics considered in this study were derived from the literature on systems usability and are the following:

- Ease of Learning: the system should be easy to be learned and handled, and the interface must be clear and objective
- Ease of Remembering: same for easiness of recalling the actions performed by the system, even if these actions are executed infrequently or after long intervals
- Error Control: same for easiness in controlling of errors, requiring that the user is clearly informed about possible causes for the error as well as on his capability to be able to fix it easily
- Efficiency: the product must do the right thing by allowing the user to operate it in such a way as to reach a high level of output and performance
- Effectiveness: the system must do the right thing in the best possible way
- Satisfaction: this metric is directly linked to users' opinion on characteristics as pleasantness and comfort of use

Each of these metrics were assessed in accordance with the following general constructs (our alternatives):

- User's easiness to complete a task for the first time
- User's first impression about using the system
- Number of attempts to learn how to complete a task
- Time required to learn how to accomplish a task successfully
- User's easiness in learning a task
- Number of different possibilities that the system provides in order to accomplish the same task; for example: standard path versus shortcut keys, shorter paths, macros, specific keys, etc
- Productivity gain with respect to the quickest way whereby the user manages to accomplish a task in comparison with the standard way the system offers by default
- Flexibility of the system to carry out tasks in different ways such as: shortcut customization, values, menus, macros, etc
- Capability of the system to guide through its execution with hints, help, warnings, etc
- Speed to accomplish a task successfully for the first time

Our criteria were taken as each of the 5 readings of a Likert scale, ranging from ***Total Disatisfaction*** (C_1) to ***Total Satisfaction*** (C_5). Therefore the order of criteria was as follows:

$$C_1 \prec C_2 \prec C_3 \prec C_4 \prec C_5$$

After collecting the data through a questionnaire and consolidating users' opinions a fuzzy triangular number was determined that resulted from the frequencies of users' opinions on the set of constructs related to each metric being assessed. Fuzzy triangular numbers are special fuzzy numbers with two very important characteristics, named the most frequent number and the spread. The most frequent number represents the value of the fuzzy number with pertinence equal to 1. The spread is half the range of the fuzzy number and represents the confidence interval for that number and it is inversely proportional to the confidence in the value of the pertinence function

Agreggation functions that can be used in Multi-Criteria Decision Analysis are:

- Weighted Average
- Ordered Weighted Average
- Choquet Integral
- Sugeno Integral
- Max and Min Operators

The Choquet Integral is a generalization of the Arithmetic Mean. It is defined with respect to a measure. Therefore the mathematical formulation of the Choquet Integral can take into account fuzzy measures and readings of numerical values over a set of evaluation criteria. These fuzzy measures allow assigning degrees of importance to all possible groups or coalitions of criteria with much more flexibility than the Weighted Average. In other words, when using the Choquet Integral we can aggregate criteria by combining scores with their respective fuzzy measures.

Here we illustrate the calculations we did for the Ease of Learning metric. To evaluate this metric 10 constructs have been used and the final result is a triangular fuzzy number (6/4) that represents the convergence of all results of the questions that make up this same metric. The fuzzy number (6/4) represents a good evaluation (6) for this metric, but its spread of 4 represents a large dispersion of users' opinions. This can be interpreted as follows: the users show to have an average satisfaction but with a considerable dispersion of opinions. Next the Choquet Integral is used as a multi-criteria ranking tool in order to determine which the most relevant constructs that should be improved are.

- A_1= easiness to complete a first task;
- A_2 = first impression about the product;
- A_3 = number of attempts made to complete a learning task;
- A_4= time to learn how to perform a task successfully;
- A_5= ease of learning a task;
- A_6= availability of alternative options to accomplish the same task;
- A_7= productivity gain with the fast mode from the default offered;
- A_8= flexibility to perform tasks in different ways;
- A_9 = ability to guide the user through the performance with tips, help, warnings, etc;
- A_{10} = agility to complete a task successfully.

How the decision matrix for the Ease of Learning metric was formed

From the data collected for the Ease of Learning metric we obtained the following table:

Construct	1 (Total INSATISFACTION)	2	3	4	5 (TOTAL SATISFACTION)	SUM
A_1	0%	7%	33%	53%	7%	100%
A_2	0%	0%	13%	67%	20%	100%
A_3	0%	7%	43%	43%	7%	100%
A_4	0%	0%	47%	40%	13%	100%
A_5	0%	3%	10%	73%	13%	100%
A_6	3%	21%	41%	24%	10%	100%
A_7	0%	7%	48%	38%	7%	100%
A_8	0%	13%	30%	43%	13%	100%
A_9	3%	17%	13%	47%	20%	100%
A_{10}	0%	3%	57%	30%	10%	100%

The question is: To which one of the 10 constructs system managers should assign the first priority in order to improve the intranet system from the point of view of Ease of Learning? The 2 steps that were followed are listed below

- Step 1: Let's organize the decision matrix. Each construct is an alternative and the criteria (ranging from C_1 to C_5) are the different degrees of satisfaction expressed by the users when filling the questionnaire.
- Step 2: Given the fuzzy measures we can now calculate the values for the Choquet Integral.

Values for the fuzzy measures related to each criterion should reflect its relative importance as compared against other criteria: it is indeed the task of an expert or decision maker to tell the relative importance of criteria as well as the kind of interaction between them through a process of elicitation – rather than to assess directly the values of the fuzzy measures

Decision matrix for the Ease of Learning metric

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}
C_1	0	0	0	0	0	0.04	0	0	0.03	0
C_2	0.07	0	0.07	0	0.04	0.21	0.07	0.13	0.17	0.03
C_3	0.33	0.13	0.43	0.47	0.10	0.41	0.48	0.30	0.13	0.57
C_4	0.53	0.67	0.43	0.40	0.73	0.24	0.38	0.43	0.47	0.30
C_5	0.07	0.20	0.07	0.13	0.13	0.10	0.07	0.13	0.20	0.10

Choquet Integral ordering for the Ease of Learning metric

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	Fuzzy measures
C_1	0	0	0	0	0	0	0	0	0	0	0.09
C_2	0.01	0	0.01	0	0	0.03	0.01	0.02	0.02	0	0.12
C_3	0.06	0.02	0.08	0.08	0.02	0.07	0.08	0.05	0.02	0.10	0.18
C_4	0.13	0.17	0.11	0.10	0.18	0.06	0.10	0.11	0.12	0.08	0.25
C_5	0.03	0.07	0.03	0.05	0.05	0.04	0.03	0.05	0.07	0.04	0.36
Choquet Integral	0.23	0.26	0.22	0.23	0.25	0.20	0.21	0.22	0.24	0.22	
Choquet Integral Ordering	4	**1**	5	4	2	3	6	5	3	5	

The use of the Choquet Integral therefore suggests that A_2 (i.e., first impression about the system) is the most important construct for the Ease of Learning metric

From similar calculations we reached the following conclusions for this particular study:

- For the Ease of Learning metric the most important construct is the first impression that the user has about the system
- For the Ease of Remembering metric the means for recalling how to use the system should be improved
- For the Error Control metric the number of errors that may lead to loss of information or rework should be minimized as much as possible
- For the Efficiency metric the ability to keep the system under control by the user should be maximized
- For the Effectiveness metric the number of steps to accomplish a given task through the system should be minimized
- For the Satisfaction metric the propensity by the user to use the product should be generally improved

For future applied research we expect to expand the scope of this Choquet Integral-based approach by taking into consideration criteria that are structured according to a hierarchy

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Спасибо большое!

Thank you very much!