MODEL FOR CLASSIFICATION AND SELECTION MOBILE TERMINAL DEVICES APPLYING FUZZY LOGIC

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ABSTRACT

This paper examines a concept and use of fuzzy logic at decision support systems in choosing adequate mobile terminal device(s). When choosing mobile device, it is necessary to take care about features of the device itself. The quality of particular device in certain area depends on those features. Affinities and user's aspirations are different and it's necessary to take care that device which suits to a business man doesn't necessarily respond to a student's needs and requests. A fuzzy logic, that is fuzzy decision system, supports and makes it easier to choose mobile device as an optimal solution depending on evaluation of device's criteria determinated by user (e.g. specific absorption rate, dimensions etc.). The process of evaluating criteria, supported by fuzzy logic, tends to determine to which quality set (e.g. high-quality, middle-quality, less-quality) belongs every particular device from certain class (e.g. mobile terminal devices) based upon previously specified criteria. Further more, device's classification list is being generated and according to it selection of mobile device is made by user.

1 INTRODUCTION

Mobile terminal devices today represent an important aspect of human lives and their implementation in everyday life can be seen in performing different activities by the same device – taking photos, recording, navigation, payments, etc. All these are activities that affect proper and correct selection of the device and according to which the user selects the mobile device.

Fuzzy logic is conceptually easy to understand, flexible, tolerant to imprecise data, it can model non-linear functions, it can be used in combination with conventional control techniques in the sense in which fuzzy logic does not necessarily replace them, but rather expands and simplifies their implementation, and it is based on natural language.

In the selection of the mobile device, it is necessary to consider the characteristics that characterise the respective device. The quality of single devices in a certain area depends on them. The affinities and the desires of the users are different and care should be taken that a device that suits for example a businessperson need not necessarily suit a student. Thus, there are various profiles of users who use the mobile terminal devices according to their needs.

Fuzzy logic, i.e. the fuzzy decision-making system, provides support and facilitates the selection of a mobile device as an optimal solution by evaluation of the device criteria determined by the user (e.g. radiation, dimensions, etc.). The process of evaluating the criteria supported by fuzzy logic, is used to determine the qualitative set (e.g. high-quality, lower quality, poor quality or extremely poor quality) to which every single device from a certain class (e.g. mobile terminal devices) belongs, based on the pre-determined criteria. Accordingly, the device classification list is made, and used to make the selection of the mobile device.
2 CHARACTERISTICS OF MOBILE DEVICE SELECTION

The characteristics of the mobile terminal devices have been classified in the following manner: each of the mentioned characteristics has been conceived as a class (e.g. Quality of production) which comprises precisely determined parameters (quality of housing and quality of keyboard), i.e. attributes for each individual class. These attributes are used to evaluate how much a certain class is better or worse at the moment at which the potential alternatives are compared (the devices themselves) in relation to single characteristics and sub-characteristics. In the paper the term class is used, and it is sometimes used instead of the term characteristic. When classifying the characteristics, care should be taken about the method of quantification of the quality of each one of them. For the classification, i.e. numerical assessment of the device characteristics in relation to the given qualitative sets, various methods are used, such as: fuzzy logic, rough sets and $k$ nearest neighbours.

All the twelve characteristics (Dimensions, Quality of production, Display, Data transfer, Camera, Battery, Memory, Navigation, Operating system, Messages, Multimedia, Radiation) form one closed system while making the decision regarding the selection of the mobile device. It should be mentioned that the decision-making process when selecting a new device need not take into consideration all the characteristics but rather only those the user finds important.

3 MODEL FOR THE CLASSIFICATION AND SELECTION OF MOBILE DEVICES BY FUZZY LOGIC APPLICATION

The problem in selecting a mobile device consists in the fact how to select from a large number of devices the one that maximally meets the needs, interests and desires of the user. Chapter two has mentioned the criteria (characteristics) with the respective attributes according to which the evaluation of the very mobile device is carried out. The evaluation of single characteristics is done using the attributes that describe the respective characteristic. Based on this, each attribute is assigned a grade. In the end, depending on the grades of single attributes the final grade is calculated which is at the same time the grade of a certain characteristic.

The user can select a mobile device from two aspects: (1) macroscopic and (2) microscopic aspect. From the macroscopic aspect, the user is presented with the classification of devices according to the given criteria depending on all the characteristics (e.g. the user wants an EXCELLENT mobile device). In other words the final grade consists of “putting together” grades of every single criterion, and as such offers an integral grade of the device itself.

From the microscopic point of view, the classification is generated also according to the given criteria but not necessarily according to all the characteristics (e.g. the user wants a mobile device which is VERY GOOD in design). Thus, the user takes into consideration at least one characteristic and according to the criteria set by the user, the mobile device is evaluated.

3.1 Fuzzy logic

Fuzzy systems are used for the approximation of the functions by adjusting the forms and positions of the functions of belonging. They are also used for modelling of any continuous function or system. The advantages of fuzzy logic are reflected in the flexibility, conceptual ease of understanding, tolerance to imprecise data, the possibility of usage in combination with conventional control techniques, basis on the natural language, etc. The application of fuzzy logic consist of several processes: taking input variables, fuzzification, fuzzy deduction, defuzzification and display of output variables.
The quality of fuzzy approximation depends on the quality of the set rules that are components of the fuzzy deduction system. Fuzzy deduction is based on the “if-then” rules. The difference in relation to fuzzy deduction is that non-fuzzy deduction allows the display of information and data in an imprecise way. For instance, the mobile device is excellent, would be an example of non-fuzzy deduction. In fuzzy deduction this same device would be 75% excellent, and 25% very good. Thus, fuzzy deduction allows that apart from black/white nuances there are also “gray nuances”. The complete process of fuzzy decision-making on the concrete example is described in the following chapters.

3.2 Conceptual model

Figure 1 shows the conceptual model and logic of its operation during the classification of a mobile device. The user determines which characteristics they find important. The number of characteristics can range from 1 to 12, the number mentioned in chapter 2. Then the user, using a linguistic expression, gives an approximate judgement, on how much a certain characteristic or characteristics are important, i.e. which device the user wants according to the set criteria. Based on this, the mobile devices are classified by means of fuzzy deduction and fuzzy logic.

3.3 Use case scenario

The user wants a device which belongs to the highest level to the group VERY GOOD for the characteristic QUALITY OF PRODUCTION. This example will explain how fuzzy logic is applied to generate the classification of the device depending on the user’s requirements. The input variables are clear numerical values (evaluation of attributes for a single characteristic) that are taken from the database for every device and they are used to determine the quality of individual characteristic – the final grade. The chronology of the process until the final solution according to Figure 2 is as follows:

- Setting of criteria by the user;
- Taking the grades of single characteristic of the device pre-generated by fuzzy logic, rough sets, k nearest neighbours, i.e. data mining methods;
- Assigning values in accordance with the set criteria to input variables of the fuzzy logic system;
- Fuzzification;
- Fuzzy decision-making;

Figure 1: Logic of the operation of the model for mobile device classification
Defuzzification;  
Assigning values of the obtained results to output variables;  
Presentation of the device classification according to the set criteria in accordance with the grades of single characteristics.

The input variables (evaluation of attribute) for a mobile phone XY are the following: Quality of the housing (3.7 [0-5]) and Quality of the keyboard (4.6 [0-5]). The output variable (evaluation of design) is the Final grade.

3.4 Fuzzification

Fuzzification is a process in which the linguistic values are represented numerically. Its task is to determine the level of belonging of the input and output variables to certain fuzzy sets by using the function of belonging. In this case a form of triangle has been selected for the function of belonging (triangular form, Figure 2). The form of the function of belonging closely defines the fuzzy set and the decision on which type of function to use is strictly related to the purpose.

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\mu = [\mu_{SUF}, \mu_{SAT}, \mu_{G}, \mu_{VG}, \mu_{E}]
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Figure 2: Fuzzy sets with the respective function of belonging

The sets and the respective functions of belonging are defined for two input variables. The ordinate shows the level of belonging to a certain fuzzy set – grade (0 – 1) which corresponds to the true or false value of plain sets. It is necessary also to define the fuzzy sets and the respective functions of their belonging to the output variable, i.e. the final grade. Fuzzy sets for input and output variables in this case are the same: Sufficient, Satisfying, Good, Very good, Excellent.

3.5 Fuzzy inference system

Fuzzy Inference System (FIS) is the procedure of formulating the deduction from the set input variables to the output variables by using fuzzy logic. The procedure allows the making of decisions or recognising of a certain pattern. For the needs of this paper the *mamdani* type of inference mechanism assumes that the functions of belonging of the output variables are fuzzy sets. The fuzzy deduction procedure includes:

- Taking the values of input variables;
- Defining of *If-Then* rules. It is necessary to define a number of deduction rules which contain the knowledge about the device assessment, referred to by the system in making the final decision (judgement) – in this example FINAL GRADE. The rules consist of *If-Then* statements which are used for the formulation of the conditional statements (premises and consequences), e.g.: *IF*
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(housing IS “good”) AND (keyboard IS “very good”) THEN (final grade IS “good”).

- A knowledge base is created from the mentioned rules. It is changed depending on the input rules.
- The application of logic operators (AND, OR, NOT).
- The application of the implication method.
- Aggregation (sum) of solutions (values) obtained by applying the rules.
- Defuzzification.

3.6 Aggregation of output variables

The aggregation of the output variables is a process in which fuzzy sets that form the output values for each of the rules are combined in a unique fuzzy set. After having applied all the possible rules, it is necessary to calculate the aggregate solution which eventually results in a concrete clear level of belonging to a certain set and facilitates the user in the final decisions in selecting the mobile device.

The aggregation of results or the aggregate solution is performed only once for each of the output variables, before the final step – defuzzification. For each rule, depending on the Quality of housing and the Quality of keyboard an output variable is generated – the Final grade. The number of output variables equals the number of rules. In order to obtain a unique solution, it is necessary to combine all the output variables into one fuzzy set – the aggregate solution.

In this paper the FuzzyLogic Toolbox has been used as part of the software tools Matlab. According to the previously defined input variables (Quality of housing = 3.7 and Quality of keyboard = 4.6) the rules have been defined according to which the Final grade is generated for every mentioned rule. Based on the final grades, the aggregate solution is calculated (Figure 3), i.e. the Evaluation of design which is 3.64 for a certain device.

Figure 3: Final grade (blue, darker color) depends on input variables (yellow)

Correlations and interdependencies of the values of input and output variables are presented by one of several types of surface graphs (Figure 4). The movement of the “Final grade” has been presented depending on the quality of the keyboard and the housing. The graph shows that the final grade is the highest in case of the highest quality of keyboard and housing. The final grade is lower if the values of the quality of the keyboard and the housing are lower.
4 CONCLUSION

Today mobile devices occupy a large part of the human everyday lives. It is therefore very important to have a mobile device that will satisfy to the greatest extent the user’s requirements. The times when mobile devices served only for calls and some very basic activities are history. Today, mobile devices are much more and it is very important to select precisely the one device that most suits the user’s affinities and needs.

Fuzzy logic helps to such an extent that it simplifies the selection procedure for the user, i.e. it directs the user to select the device according to the characteristics the user has provided. The proposed model of the system for the classification and selection of mobile devices is based on fuzzy logic. The usage of fuzzy logic makes it possible to generate a list of devices that to the largest extent match the initial settings, i.e. criteria according to the obtained results.

In selecting a mobile device using fuzzy logic, the user’s requests are the most important. In selecting mobile devices fuzzy logic has as its primary objective better understanding of the affinities of the user, not by prescribing certain universal recipes for the selection of the mobile device, but rather by approaching the user in a systematic way, and focusing on their needs and desires.

The model for the classification system and selection of mobile devices described in this paper allows simple adaptation and it can be very easily adapted to other needs. The application of fuzzy logic is very widespread and user-friendly for several reasons that are reflected in the flexibility, conceptual ease of understanding, tolerance to imprecise data, possibility of usage in combination with conventional control techniques, being based on natural language, etc.

REFERENCES

