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Fuzzy Processing of Uncertain Data

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***Abstract*—**In practice, we often come across situations where it is necessary to make decisions based on incomplete or uncertain data. In control systems it may be due to the unknown exact mathematical model, or its excessive complexity (e.g. nonlinearity) when it is necessary to simplify it, respectively, to solve it using a rule base. In the case of databases, searching data we compare a similarity measure with of the requirements of the selection with stored data, where both the select query and the data itself may contain vague terms, for example in the form of linguistic qualifiers. In this paper, we focus on the processing of uncertain data in databases and demonstrate it on the example multi-criteria decision making in the selection of variants, specified by higher number of technical parameters.

***Keywords*—**fuzzy logic, linguistic variable, multicriteria decision

I. Introduction

THE primary task was to implement the system that will handle uncertain information in databases. To simplify purchases on the Internet, a modern shop with expert knowledge fuzzy system was designed. This system is able to advise customers entering electronic shops how to purchase the goods as well as salesmen to sell the goods. It should intuitively evaluate vague customer requirements. As the development environment for this task, the most common combination of PHP programming language and MySQL database was chosen because it is licence free. The goods sold in the shop are laptops, because they are nowadays very popular, especially due to their mobility.

II. Uncertainty in Databases

Uncertainty in the database was implemented using fuzzy logic, which provides possibilities of robust work with uncertain data. The basic strength of fuzzy logic is easy work with natural language expressions and their subsequent processing.

- *Fuzzy logic* - the usual practice is required to achieve the greatest accuracy, absolute precision is essentially unattainable. The measured size of the table is, e.g., 3 m; accurate measuring devices will automatically determine inaccuracy in dm, cm, mm, etc. Fuzzy logic applied in the described expert system deals with uncertain data and is able to make a final decision [3].
- *Natural language (linguistic variables)* - we use the terms of ordinary human speech. The advantage of these expressions is their intuitive understanding. E.g. if you want to learn something new, we do not know the exact details on the data, but it is sufficient to have only a few vague words to understand. For more details, see the following issues in [2].
- *Application functionality* - Data processing that uses fuzzy logic is based on determination of the interval, which the linguistic expressions belongs to, and then the application finds all laptops in it. These laptops are automatically assessed by evaluating functions implemented in the application. The laptops with the highest value of the evaluation functions are displayed to users.

A table of goods was proposed to implement the requirements mentioned above. It was necessary to focus on the important parameters of laptops, which will be evaluated by the given fuzzy system. Further we will investigate the way of linguistic variables design and the subsequent storage of fuzzy numbers for further processing.

III. Fuzzy Expert System

An expert system is a computer program capable of deciding about the given problem on the basis of information knowledge obtained from experts.

TABLE I
Linguistic Variables

Column Name	Column Type	Description
ID_LIN	int(10)	Identification of linguistic variables
HARDWARE	varchar(25)	Identification of the type of hardware that is defined by the linguistic variable
NAME	varchar(30)	Name of the linguistic variable
FROM	varchar(30)	Beginning of linguistic variable function
MIDDLE	varchar(30)	Middle of linguistic variable function.
IN	varchar(30)	End of linguistic variable function.
FUNCTION	enum('1','2','3')	Function definition of linguistic variables 1 = low, 2 = middle, 3 = maximum

A. Tables of Expert System

For modelling of linguistic variables in natural language, Table 1 was proposed. For storage of the fuzzy ranking laptops, Table II was designed [4].

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These data tables are to most important. However , the application offers much more data tables, e.g., table of laptops catalogue, users, orders, etc. More details including their relation can be found in Fig. 1.

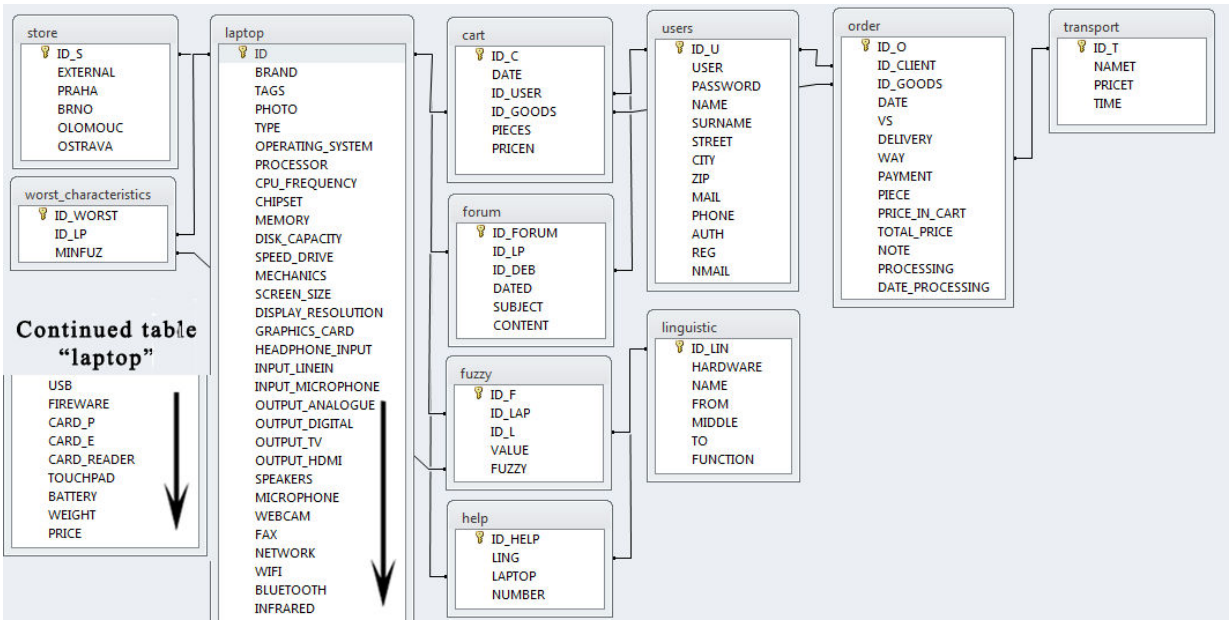

Fig. 1 Relationships of all tables in our database application

TABLE II
FUZZY RANKING

Column Name	Column Type	Description
ID_F	int(10)	Identification of fuzzy values
ID_NOT	int(10)	Identification of the laptop
ID_L	int(10)	Identification of the linguistic variable
VALUE	varchar(35)	Laptop variable which is asserted
FUZZY	varchar(35)	Fuzzy ranking based on linguistic variables

B. Selection of laptop parameters

When buying a laptop we consider several parameters, which are the most important for the user. Of course these requirements can differ; it is therefore necessary to design such elements that will best suit most users. In the described application the following parameters of laptops were designed:

- *Brand* - Achieving the lowest price is reflected in the quality of the laptops. However, there are companies that take pride in quality. Therefore the brand was included into the decisions and it enables to show whether the user prefers the guaranteed quality of a laptop.
- *Screen size* - Development of laptops brought about a progressive miniaturization of components and thereby the laptops size reduction, enabling greater mobility, which is their main advantage.
- *Processor* - creates a brain of laptops; the better and faster the processor is, the faster the laptop.
- *Hard disc* - is a basic drive for the operating system, user data and programs. Nowadays the trend is to have a hard disc with an extremely high capacity.
- *Operational memory* - The speed is closely connected with the operational memory, the greater is the amount of memory, and the larger is the space for running applications.
- *Graphics card* - It is closely connected with the applications that are very graphics-intensive, i.e. mainly videos and computer games.
- *Batteries* - are joined with the mobility of a laptop, because we do not always have the possibility to plug the electric power, and therefore the ability to operate as long as it is necessary is required.
- *Weight* - closely relates to the size of laptops and mobility, thus the smaller the laptop is, the less weight is achieved.
- *Price* - closely relates to all of the above parameters and mainly depends on the laptop quality and size.

C. Modelling of fuzzy linguistic variables

A modelling system to define the linguistic variables of all laptops was proposed. The model contains the following linguistic variables:

- *Brand* – best quality, quality, reasonable, , neutral, cheaper,
- *Screen size* - the largest, larger, normal, smaller, the smallest
- *Processor* - the fastest, fast, average, slow, the slowest,

- *Hard disc* – the largest space, enough space, average space, small space, the smallest space,
- *Memory* - the highest, middle-sized, the lowest,
- *Graphics card* – for work, for computer games,
- Batteries - large, average, small,
- *Weight* – the lightest, lighter weight, average, heavier, the heaviest,
- *Price* – the most expensive, more expensive, reasonable, cheaper, the cheapest.

D. Proposal of linguistic variables

Having designed all of the above linguistic variables, we can start introducing these variables into our expert system. Each page shows the interval of the parameter that helps to modelling. Fig. 2 shows the form for insertion (editing) of new linguistic variables and it contains the following boxes:

- *Hardware* - This box is pre-filled and cannot be changed. It serves to identify which laptop parameter is modelled,
- *Name of linguistic variables* – Here we write the name of our linguistic variable for example, "the smallest"
- *The starting interval ("from" value)* - here we write the value of the right interval margin, where the degree of membership is "1" ("0") and for higher values is less (greater) than "1" ("0"), the default option for this parameter is 'n'
- *The interval middle* - here we write the value where the evaluation of the selected features begins decrease (or increase)
- *The ending interval ("to" value)* – here we write the value of the right interval margin, where the degree of membership is "1" ("0") and for higher values is less (greater) than "1" ("0"), the default option for this parameter is 'n'

For correct calculation of uncertainty, it is necessary to assign only numeric values to the interval parameters "from", "middle" and "to".

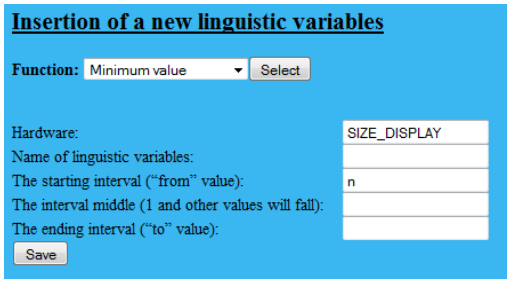

Fig. 2 Insertion of a new linguistic variables

E. Generating fuzzy evaluation based on linguistic variables

Generating fuzzy ranking on the base of linguistic variables was implemented by means of computational functions. A part of this web page is an automatic control assessment of all laptops for given linguistic variables. If by chance, a laptop and its parameter for the linguistic variables had not assigned their ranking, then the application would indicate it.

Since assigning a fuzzy ranking to each new laptop would have been very laborious, it was necessary to implement an automated system for its evaluation. Similarly, after deleting it is necessary to remove the laptop and its ranking in the corresponding tables. An automated evaluation is processed in the following locations:

- When a new laptop is inserted, then it will be automatically evaluated and included into the expert system,
- When a laptop is edited then this operation will also include an edition of its fuzzy ranking.

An automated fuzzy calculation was designed to facilitate the work with the expert system, because to upload or edit new laptops may, e.g., a salesman, but we have to ensure that its ranking will be determined. Finally, we have to remind the users that if a new linguistic variable is created (or updated) its ranking is not automatically changed in the table "fuzzy" because it is assumed that the decision core of expert system will be looked after by an expert who will monitor the fuzzy evaluation, whether it corresponds to the reality set and when he is satisfied with his settings, then he will press the Save button, which confirms the contents change. This approach seems to be preferred for reasons independent of the knowledge expert system for modelling, i.e. the database is updated at the moment when an expert finishes his jobs.

F. Search for laptops based on fuzzy expert system

A knowledge-based expert system in the e-shop gives us great possibilities. Besides to the catalogue described in natural language of users, it offers the information retrieval using natural language expressions also for those users who do not have sufficient technical knowledge about the parameters of laptops. All of the above defined laptop parameters are included in a simple explorer, where we can select all linguistic variables defined in the previous part of this paper. Using them we can specify requirements the laptop should meet in the natural language, what.

Search for vague information is dealt with so that we as "moderate" price and the script first find out the laptops belonging to the linguistic variables and the output profile. The above described mechanism would work perfectly for a single parameter search. Because our search engine has nine options from which the users can select and specify their requirements, a compromise in the search has been proposed. For these cases searches were used using multicriteria decision making. Each line of search engine must find out what actually the given vague information means, and these laptops can be saved in an auxiliary table. We continue with the following line, and these laptops are again added to the auxiliary table. Once you pass through the total of all the parameters using multi-criteria decision-making from an auxiliary table, you can select a laptop that is then listed to the user. We also solved what happens when the user selects a parameter. The solution is based on the idea that when a user

selects a parameter, this parameter is not important for him/her, i.e. the search algorithm selects the laptops which, in this parameter, have a degree of membership greater than 0.5.

G.E-shop with fuzzy expert system

E-commerce allows you to select from the catalogue, in most cases, in some categories and detailed descriptions of goods. Most e-shops offer a product search based on user requirements. In our case, expert knowledge system to search our uncertain data was used. . This system also offers the possibility of ordering, delivery and payment for goods. More sophisticated applications provide links to e-shops with the bookkeeping used in the shop, showing the number of pieces in stock, discussions about the goods and payment by credit card over the Internet. The e-shop is designed so that the administrator application should minimize labour and handling orders and replenishment the need to look after the store personnel. The following table has been implemented in the e-shop: :

- administration system
- catalogue goods
- cart
- system for ordering goods,
- system to dispatch goods
- storage system
- discussion

In the e-shop, the administration system was implemented with five levels of rights: Anonymous, User, the right of ordinary customers, Editor's law for vendors, Admin is the right to knowledge engineers (experts) and SuperAdmin is the only account that the administrator or the owner of the application owns.

The e-shop offers the opportunity to purchase at the store or shipping address. We implemented the most modern methods of paying for goods (cash, bank transfer, online payments and credit card). The ordering and deals system was designed according to the latest trends.

The application is a storage system which informs the customer about the number of goods at five different stores (off-site storage, Storage: Prague, Brno, Olomouc and Ostrava), and last but not least, there is a possibility of discussion about any laptop between customers and staff. Figure 4 is a sample catalogue of laptops. For more information, see the thesis [1].

Fig. 3 Calculation of fuzzy values

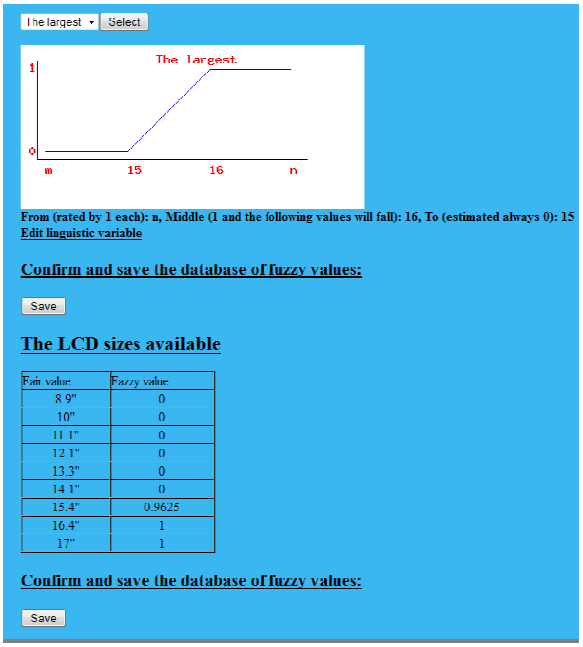

Fig. 4 Calculation of fuzzy values

Fig. 5 Search query results and a search

Fig. 6 Sample survey catalogue laptops

IV. Conclusion

The goal of the paper was to design and implement an application for the processing of uncertain data in databases. When determining the requirements the application should satisfy, it was decided that the uncertain data will represented customer requirements considering the purchase of goods. As basic goods for the purchase, laptops were chosen because nowadays they are very popular and people frequently prefer them because of their mobility.

In our work we have created a shop with an expert knowledge system, which aims to advice clients who are in the grasp of the parameters of laptops. For the other customers, a classical catalogue has been implemented in the form known from various shops on the internet engaged in selling computers.

The development was primarily focused on simplicity, clarity and intuitive handling for both the users and experts who will work with our model of fuzzy expert system. The design of the application was tailored to needs of our knowledge expert fuzzy system.

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