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Determination of the satisfaction attribute in usability tests using sentiment analysis and fuzzy logic

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Abstract

With the growth in the number of applications deployed in cloud app stores, usability has become a fundamental attribute to ensure end-user productivity and enterprise competitiveness. According to ISO 9241-11, the three attributes that determine the usability of a product are effectiveness, efficiency and satisfaction, the latter being the subjective attribute of usability. In conventional user tests, the satisfaction attribute is determined using perception questionnaires, being a challenge to determine this attribute more objectively, given the limitations of surveys in terms of veracity and subjectivity. Based on the above, in this article we propose as a contribution, the construction of a system based on fuzzy logic for the estimation of the usability satisfaction attribute in user tests, which has as inputs both the level of satisfaction obtained from the answers to the post-test questionnaire, and the level of satisfaction obtained from the polarities of the opinions of the test users, determined by means of sentiment analysis techniques. The proposed fuzzy system is intended to serve as a reference to be replicated at the academic and enterprise level in the conduct of usability tests and specifically in the more objective determination of the satisfaction attribute based on the advantages of fuzzy logic and sentiment analysis techniques.

Keywords: fuzzy logic, satisfaction level, sentiment analysis, usability.

1 Introduction

With the growth in the number of applications deployed in cloud app stores and the number of users consuming them, usability has become one of the key attributes contributing to the competitiveness of software companies and end-user productivity [8, 13, 25]. According to Nielsen, usability is an attribute of software quality, which evaluates how easy to use the graphical interfaces of software systems are for users and is defined by 5 main attributes: learnability, efficiency, memorability, error tolerance and satisfaction [5, 20]. Also, according to ISO 9241-11, usability is defined as the degree to which a software product can be used by specific users to achieve specific objectives with effectiveness, efficiency and satisfaction [11, 19, 21, 30]. Similarly, according to ISO 9126-1, usability is defined as the ability of a software product to be understood, learned, operated and attractive to the end user [9, 28]. Thus, according to the previous definitions, it is possible to observe how user perception or satisfaction is a key attribute that determines the usability of a software product.

One of the most effective ways to evaluate the usability of a software product is through the so-called user tests, in which a set of users perform tasks in a controlled environment or usability laboratory, which are supervised by a set of evaluators in order to determine the attributes that define usability, where the attributes defined by ISO 9241-11 (effectiveness, efficiency and satisfaction) are usually the most widespread [6, 7]. In a conventional user test developed in a usability laboratory, effectiveness can be determined from the percentage of tasks completed by the users, efficiency can be obtained by relating the time spent by each user in performing a task with respect to the time estimated by the evaluator, while satisfaction is determined in the traditional way through the use of so-called perception surveys [1, 10]. Thus, effectiveness and efficiency are considered the objective attributes of usability, while satisfaction is considered the subjective attribute. Thus, one of the challenges of user testing is the more objective determination of the satisfaction attribute, given the limitations of perception surveys in terms of their veracity and subjectivity[23].

Among the most widespread approaches nowadays for perception analysis in other contexts such as marketing based on the opinion of customers in social networks or e-commerce portals regarding the products and services offered by companies, it is important to highlight the techniques of opinion mining or sentiment analysis, in which through the use of natural language processing (NLP) methods, the polarity value (positive, negative and neutral) of an opinion is determined [15]. In this sense, there are different researches that evidence the application of sentiment analysis techniques in the context of marketing. Thus, in [16] a method based on sentiment analysis supported by a lexicon or domain lexicon is proposed, from which a case study is developed to analyze the polarities of the opinions of customers of the electricity service in the United Kingdom. In [2] an opinion mining study was developed on the comments made on the social network twitter regarding typical Halal tourism destinations, in order to identify the most popular sites with the best perception or positive polarity. In [31], a sentiment ontology is proposed to perform context-sensitive sentiment analysis studies on online stock market to support investment-level decision making and risk perception of public companies. In [22] an approach based on machine learning, time series and sentiment analysis is proposed to predict the monthly total vehicle sales in the US, so that a dataset was formed with the polarities of twitter users' opinions and the values obtained in the stock market. In [23] a study was developed based on sentiment analysis of customer opinions of the world's top 26 cosmetic brands, in order to identify relative customer satisfaction by using inverse term-frequency document frequency analysis, as well as to determine the causes of positive and negative opinions. In [29] a sentiment and emotion analysis study is developed on tweets related to the topic of cryptocurrencies, making use of deep learning methods and in order to identify the perception of users with respect to cryptocurrencies. In [15] a sentiment analysis approach for online product reviews in the context of marketing was proposed, which made use of heuristic algorithms and was validated using a dataset of movie reviews.

The application of opinion mining and/or sentiment analysis techniques in the context of marketing gives the possibility of extrapolating these methods to the field of usability and specifically in the analysis of the satisfaction attribute in user tests, however, as evidenced in the previously described works, although the positive polarity is considered as an indicator of customer perception, in none of these works was the calculation of a specific level of satisfaction from the three polarities obtained through sentiment analysis performed. Likewise, given that a user test includes within its post-test questionnaire both quantitative questions (traditionally used as indicators of the satisfaction attribute) and open questions that collect the users' opinion, it is of great interest to obtain a combined level of satisfaction, which represents a challenge considering the different scales presented by the quantitative questions and the ranges of the polarities of the opinions. In this sense, the application of fuzzy logic can contribute to obtain a combined numerical and linguistic level of satisfaction, which is more intelligible and representative for the coordinators of a user test.

Fuzzy logic can be understood as a mathematical tool that provides a simple way to reach a specific conclusion, starting from input data that may be undefined, imprecise, or vague [14, 18, 32]. Thus, the use of fuzzy logic allows the generation of intelligible results that relate numerical data to linguistic terms that are close to natural language [3, 4, 26]. Thus, in this article we propose as a contribution the construction of a system based on fuzzy logic, which receives as input both the average of the quantitative ratings of the post-test questionnaire, and the composite value of the polarities of the users' opinions in the post-test questionnaire, so that from these inputs, the system calculates a combined output satisfaction level using a set of inference rules that relate the fuzzy sets determined for the inputs. Given the relevance of the proposed approach in terms of estimating the satisfaction attribute in a more objective way, the proposed system is intended to be replicated in the academic and enterprise context to support the development of user tests and specifically in the estimation of the satisfaction attribute based on the use of sentiment analysis and fuzzy logic.

The rest of the paper is organized as follows: section 2 describes the different methodological phases used for the development of this research; section 3 presents the results obtained through this research, which includes a description of the functionalities provided by the system, as well as a proof of concept in which the usefulness of the proposed system is verified by using the data corresponding to an example test with 5 users; finally, section 4 presents the conclusions and future work derived from this research.

2 Methodology

For the development of the present research, the four phases of the iterative research pattern proposed by Pratt [24] were taken into consideration: observing the application, identifying the problem, developing the solution, testing the solution (see Figure 1).

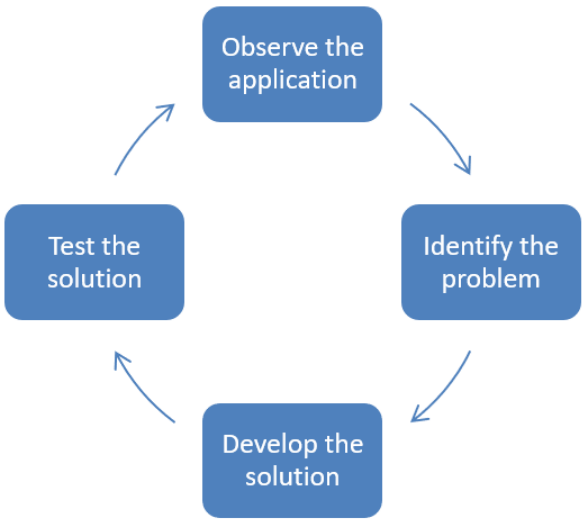

Figure 1: Methodology considered (Source[24])

In phase 1 of the methodology, user tests were characterized in order to identify the different stages that make up this type of test, as well as the way in which the satisfaction attribute is determined in a conventional way. Thus, it was possible to identify that conventional user tests developed in a usability laboratory consist of 5 stages: confidentiality agreement, pre-test questionnaire, task list, post-test questionnaire and analysis of results (see Figure 2).

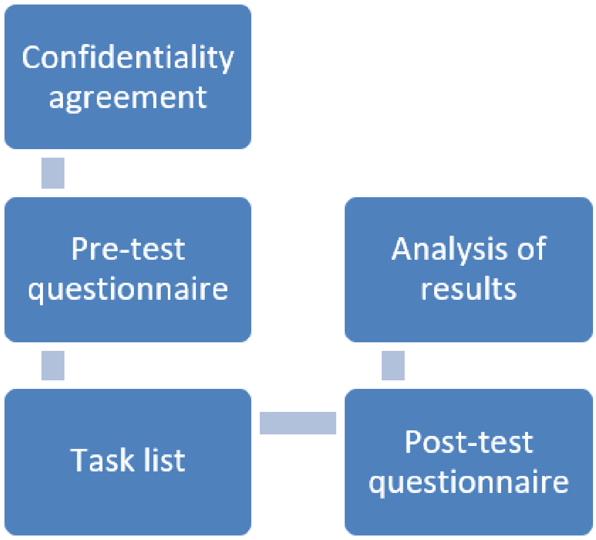

Figure 2: Stages of user tests (Source Own)

In the confidentiality agreement, the user is informed and guaranteed that the different data obtained in the test will be used only for academic purposes. Within the pre-test questionnaire a set of data are obtained regarding the user's profile, as well as data related to the user's previous experience with tools like the evaluated software. Once the pre-test questionnaire is completed, the user proceeds to develop a set of tasks defined and supervised remotely by the usability test coordinators, who, while supervising the tasks, record the time spent in the development of each task, as well as the level of compliance or development of each task by each user, to determine the effectiveness and efficiency attributes. When the development of the usability test tasks concludes, the users proceed to fill out the post-test questionnaire, which through quantitative and qualitative questions seeks to determine the user's perception and satisfaction with respect to the evaluated software. Thus, to determine the satisfaction attribute quantitatively for each user, the average of the questions in the post-test questionnaire involving satisfaction is traditionally used as an indicator, as shown in Eq. 1.

$$sat\_pos = \frac{q1 + q2 + q3 + .. + qn}{n}. \tag{1}$$

where $q1$, $q2$,....,qn, represent the rating assigned to each of the questions in the post-test questionnaire considered in the calculation.

In a complementary way, it is possible to take advantage of affective computing and specifically sentiment analysis techniques to determine the users' perception of a usability test, considering the three polarities of an opinion (positive, negative and neutral). Thus, using an adaptation of the approach proposed by the opinion mining library VaderSentiment [17, 27], it is possible to obtain a composite value of the polarities which is an indicator of the users' level of perception, as shown in Eq. 2.

$$sat\_sent = \left(\frac{x}{\sqrt{x^2 + a}} + \frac{\sqrt{1 + a} - 1}{\sqrt{1 + a}} \right) \tag{2}$$

where x represents the difference between the positive polarity and the negative polarity (see Eq. 3).

$$x = pol_{pos} - pol_{neg} \tag{3}$$

while a corresponds to an arbitrary value that is added to the first root of the equation with the purpose that when the value of x is maximum, i.e. 1, the root can be exact. Thus, the possible values of a can be 3, 8, 15, etc., considering that these allow obtaining values that have exact square root (4, 9, 16, etc.) when the value of x is 1.

It is important to mention that the neutral polarity is equally distributed between the positive and negative polarity, so the value of x is obtained by subtracting the positive and negative polarities.

Finally, in the results analysis stage, the data from the pre-test and post-test questionnaires are consolidated for the analysis of the user profiles and the determination of the percentage or level of usability, considering the percentages of effectiveness, efficiency and satisfaction obtained per user and for the entire test, as shown in (see Eq. 4)

$$usability\_level = \frac{\%effectiveness + \%efficiency + \%satisfaction}{3} \quad (4)$$

It is worth mentioning that in $usability\_level$, the satisfaction percentage can be determined by multiplying by 20 the value obtained in sat_pos or by multiplying by 100 the value obtained in sat_sent, considering the ranges of the values of these equations.

Once the phases of a conventional user test have been characterized, as well as the methods used to determine the level of satisfaction in a traditional way or by using sentiment analysis techniques, the design of the fuzzy system was carried out in phase 2 of the methodology, which includes the definition of the membership functions for both the system input variables (average of the quantitative ratings of the post-test questionnaire (sat_pos) and composite value of the polarities of the users' opinions in the post-test questionnaire (sat_sent)), and for the system output variable or satisfaction level (sat_level). Similarly, in this phase, the inference rules relating the input variables to the output satisfaction level were specified. Thus, Figure 3 shows the membership functions defined for the 3 fuzzy sets (poor, average, good) associated to the input variable sat_pos, which is obtained from equation 1 and its range is from 0 to 5.

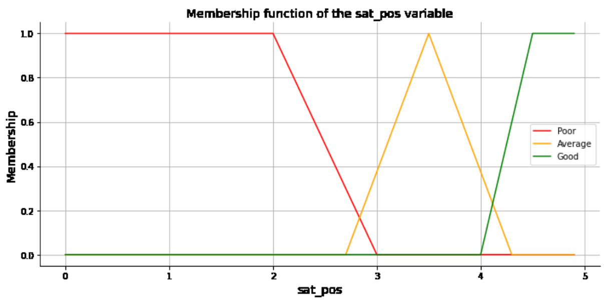

Figure 3: Membership functions for the input variable sat_pos (Source Own)

Similarly, Figure 4 shows the membership functions defined for the 3 fuzzy sets (negative, neutral, positive) corresponding to the input variable sat_sent, which is obtained from equation 2 and is in the range from 0 to 1.

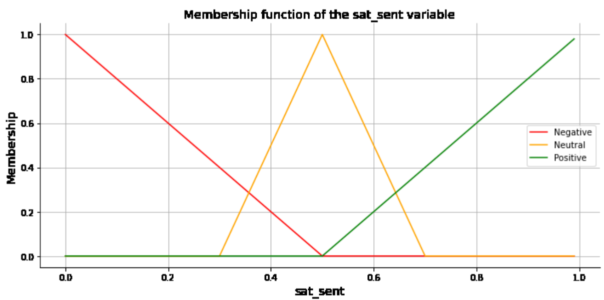

Figure 4: Membership functions for the input variable sat_sent (Source Own)

On the other hand, Figure 5 shows the membership functions corresponding to the 4 fuzzy sets (poor, fair, good, excellent) that describe the output variable or level of satisfaction, which is in the range from 0 to 100 and is determined by the fuzzy system from the system inputs and the inference rules (see 1).

Likewise, Table 1 shows the 9 inference rules that relate the input variables (sat_pos and sat_sent) to the output satisfaction level (sat_level), thus allowing the determination of this value in numerical and linguistic terms. These inference rules were defined in FCL (Fuzzy Control Logic) language and

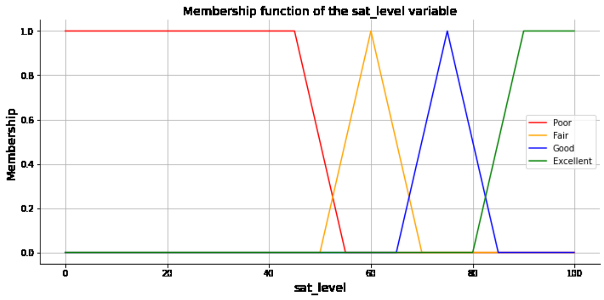

Figure 5: Membership functions for the input variable sat_level (Source Own)

Table 1: Defined inference rules

Id	Inference Rule
1	IF sat_pos_test IS poor AND sat_sent IS negative THEN sat_level IS poor
2	IF sat_pos_test IS poor AND sat_sent IS neutral THEN sat_level IS poor
3	IF sat_pos_test IS poor AND sat_sent IS positive THEN sat_level IS fair
4	IF sat_pos_test IS average AND sat_sent IS negative THEN sat_level IS poor
5	IF sat_pos_test IS average AND sat_sent IS neutral THEN sat_level IS fair
6	IF sat_pos_test IS average AND sat_sent IS positive THEN sat_level IS good
7	IF sat_pos_test IS good AND sat_sent IS negative THEN sat_level IS fair
8	IF sat_pos_test IS good AND sat_sent IS neutral THEN sat_level IS good
9	IF sat_pos_test IS good AND sat_sent IS positive THEN sat_level IS excellent

have an antecedent that relates the system inputs and a consequent that indicates the output value of the satisfaction level.

Once the membership functions were defined for the input variables and for the output variable of the system, as well as the inference rules that relate the inputs and the output, in phase 3 of the methodology the fuzzy logic system was implemented to estimate the level of satisfaction in user tests using the Java programming language and specifically the JFuzzyLogic library, which allows the definition of membership functions and inference rules in the FCL language, as well as the mathematical and graphical analysis of the system variables for different input values. Similarly, the fuzzy system made use of the javacsv library for processing the system input files, which contain the post-test questionnaire data associated with user satisfaction and opinions regarding the interaction. Regarding the analysis of the opinions, the fuzzy system used the VaderSentiment library to obtain the polarities associated with each user's opinion. Thus, the implemented system allows the usability test coordinators to enter both user ratings to the post-test questionnaire questions related to satisfaction, as well as user opinions regarding the interaction, in order to determine the combined satisfaction level per user and for the entire usability test. Finally, in phase 4 of the methodology, the functionality and usefulness of the proposed fuzzy system was verified through the development of a proof of concept, in which the data associated with a usability test with 5 users were used.

3 Results

In this section the results obtained in the present research are specified, which includes the description of the system's graphic interface and its functionalities, as well as a proof of concept in which the functionality and usefulness of the proposed system was verified.

3.1 Construction of the fuzzy system

As previously mentioned, the fuzzy system was implemented in Java language using the jFuzzyLogic library and its graphical interface consists of 4 tabs: "Questions Post-Test", "Sentiment Analysis", "Fuzzy Satisfaction Analysis", "Membership Functions" (see Figure 6). In the "Questions Post-Test" tab, the fuzzy system automatically loads from a .csv file, the ratings made by the test users to the different questions of the post-test questionnaire that involve satisfaction, so that by pressing the "Calculate" button, the system determines the degree of satisfaction per user and for the entire test using Eq. 1. Likewise, once the above calculations have been made, the system generates and displays a bar chart with the satisfaction levels associated with each of the test users, using the free JFreeChart library. The values calculated in this tab thus correspond to the input variable *sat_pos* of the fuzzy system. As an example, Figure 6 shows the data from a usability test with 5 users, where two questions from the post-test questionnaire were taken to determine the satisfaction attribute (rated on a scale of 0 to 5). Within this sample data, it is possible to observe mathematically and graphically how the highest level of satisfaction is 3.5 (user 3), while the lowest level of satisfaction is 2.5 (users 2 and 4). Likewise, the average satisfaction level is 2.9.

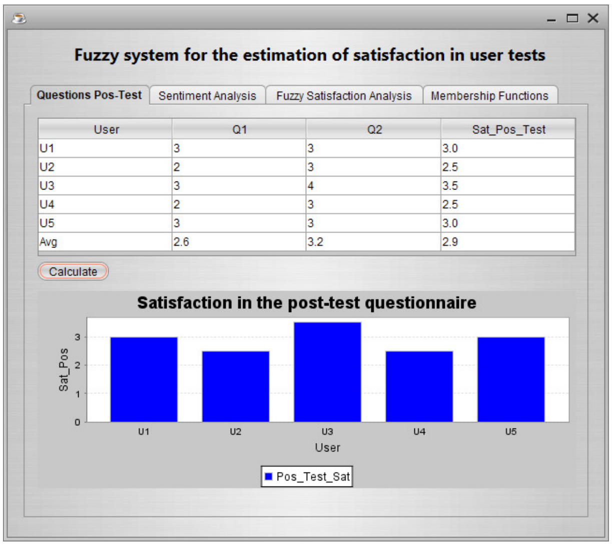

Figure 6: Main system interface (Source Own)

Continuing with the description of the proposed system, Figure 7 presents the "Sentiment Analysis" tab, in which the system automatically loads from a .CSV file the opinions made by the test users within the post-test questionnaire, so that by pressing the “Calculate” button the system determines the 3 polarities (positive, negative, and neutral) associated with each opinion, as well as the composite satisfaction level based on sentiment analysis using equation 2. Likewise, once the above calculations have been made, the system generates and displays a bar chart with the level of satisfaction based on sentiment analysis associated with each of the opinions of the test users. It is worth mentioning that the values calculated in this tab correspond to the input variable *sat_sent* of the fuzzy system. As an example, it is possible to observe how from the test opinions loaded and presented in Figure 7, it was obtained that all opinions have a satisfaction level below 0.5 (in the range from 0 to 1), being the highest level 0.464 (user 4), which is related to the higher value of the negative polarity with respect to the value of the positive polarity for all users.

On the other hand, Figure 8 shows the "Fuzzy Satisfaction Analysis” tab of the proposed fuzzy system, in which the data obtained for the satisfaction level of the post-test questionnaire are loaded from the "Questions Post-Test" tab and the satisfaction level data obtained by means of sentiment analysis techniques from the "Sentiment Analysis” tab, so that by pressing the "Calculate" button the combined satisfaction level per user and for the entire usability test is determined, by performing the process of defuzzification of the inputs (*sat_post* and *sat_sent*) using the membership functions associated with them and obtaining the output satisfaction level or fuzzyfication through the use of the inference rules and the membership functions of the output variable.

In addition to obtaining the combined satisfaction level per user and for the entire usability test, the system allows to display for a given user the membership function of the output variable (*sat_level*) together with the value and level determined from the inputs, the membership functions and the inference rules activated after the defuzzification process. On the other hand, in this tab, it is possible by clicking on the “Report” button, to generate a report with the results associated with the calculation of the combined satisfaction level for a given user and for the entire test. As an example, from the sample data loaded in the “Questions Post-Test” and “Sentiment Analysis” tabs, a combined output

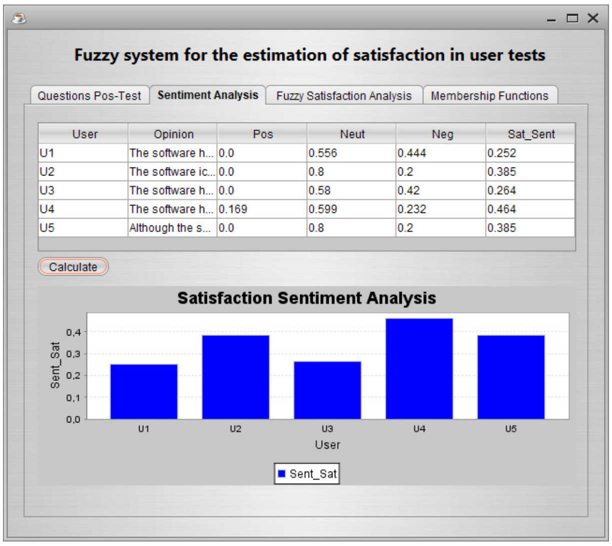

Figure 7: Sentiment Analysis tab of the system (Source Own)

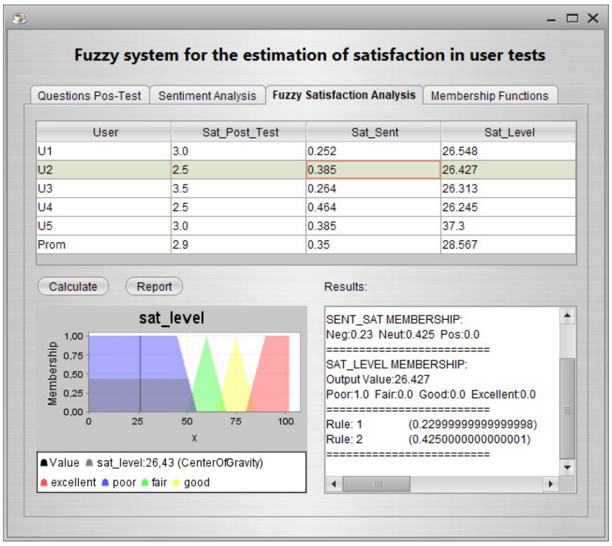

Figure 8: Fuzzy Satisfaction Analysis tab of the system (Source Own)

satisfaction level of 26.427 is obtained for user 2, which corresponds to the poor fuzzy set. Similarly, it is possible to observe that in determining this level of output, rules 1 and 2 of Table 1 were activated, with rule 2 obtaining a higher level of membership.

Finally, Figure 9 shows the interface of the "Membership Functions" tab of the fuzzy system, whereby choosing a specific user and pressing the "Consult" button, it is possible to visualize the membership functions of the inputs and outputs of the system, as well as the values and levels obtained in the fuzzification and defuzzification process. As an example, for the sample data loaded in the "Questions PostTest" and "Sentiment Analysis" tabs, it is possible to observe how for user 3 the fuzzification process allowed to determine that the input variables *sat_post* (3.5) and *sat_sent* (0.264), were classified in the fuzzy levels or sets "average" and "negative" respectively. The above allowed obtaining an output value of 26.313, which corresponds to the fuzzy set or "poor" level.

3.2 Proof of concept

In order to verify the functionality and usefulness of the proposed fuzzy system, a proof of concept was developed in which data was collected from a usability test with 5 users, from which 3 questions were selected for the post-test questionnaire to determine the conventional level of satisfaction. Thus, Table 2 presents the ratings assigned to the 3 questions selected from the post-test questionnaire,

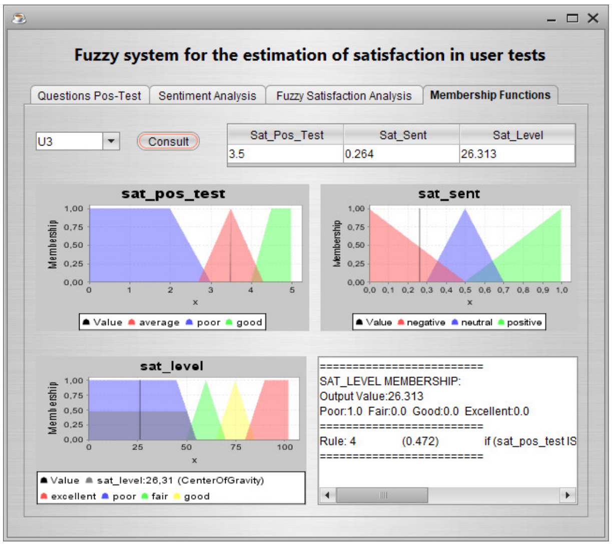

Figure 9: Membership Functions tab of the system (Source Own)

Table 2: Proof of concept data

User	Q1	Q2	Q3	Opinion
1	4.0	4.2	3.5	The software allows to accomplish the tasks adequately, but it can improve the organization of the different options in the menus.
2	3.6	3.8	3.9	The software serves its purpose but some icons are unintuitive.
3	3.2	3.3	3.5	Some main functions of the software are difficult to find in the options menu.
4	3.1	3.4	3.0	Although the software allows to perform the tasks the response times are not adequate and the design is inconsistent
5	4.0	4.3	4.1	The software fulfills its purpose but can improve the consistency of its different views

as well as the opinions corresponding to each user with respect to the interaction with a given test software.

Once the data presented in Table 2 were entered into the proposed fuzzy system, it allows determining both the conventional satisfaction level (*sat_pos*) from the columns (Q1, Q2 and Q3) and considering the membership functions in Figure 3, and the satisfaction level based on sentiment analysis (*sat_sent*) using the Opinion column, the VaderSentiment API and the membership functions in Figure 4. Similarly, from the values of the input variables (*sat_pos* and *sat_sent*), the system determines the value of the output variable (*sat_level*) per user and for the entire test, based on the inference rules and membership functions in Figure 5. Thus, the results obtained by the fuzzy system from the data in Table 2 are presented in Table 3.

Table 3 consists of 6 columns: user, *sat_pos*, *sat_sent*, *sat_level*, qualitative level and rules activated. The "user" column refers to the identifier of each of the users who participated in the

Table 3: Results obtained in the proof of concept

User	sat_pos	sat_sent	sat_level	Qualitative Level	Rules Activated
1	3.9	0.633	66.743	Fair	Rule 5 (0.3349) Rule 6 (0.266)
2	3.767	0.5	60	Fair	Rule 6 (0.66625)
3	3.333	0.407	41.081	Poor	Rule 4 (0.186) Rule 5 (0.5349)
4	3.167	0.451	46.97	Poor	Rule 4 (0.098) Rule 5 (0.5837)
5	4.133	0.675	79.136	Good	Rule 5 (0.125) Rule 6 (0.209) Rule 8 (0.125) Rule 9 (0.266)
Total	3.66	0.533	61.605	Fair	Rule 5 (0.799) Rule 6 (0.066)

usability test. The “*sat_pos*” column corresponds to the first input of the system and comprises the level of satisfaction determined from the ratings of the post-test questionnaire. The “*sat_sent*” column is the second input of the fuzzy system and corresponds to the level of satisfaction determined from the use of sentiment analysis techniques on user opinions. The “*sat_level*” column corresponds to the level of satisfaction estimated by the fuzzy system based on the inference rules and Mamdami’s method. Similarly, the “*qualitative_level*” column corresponds to the fuzzy set or qualitative level associated with the output satisfaction level determined by the fuzzy system. Finally, the column "rules activated" corresponds to the rules in Table 1 that are activated in the process of determining the level of satisfaction, together with their respective degree of belonging. From the results presented in Table 3, it is possible to observe how the lowest level of satisfaction obtained by the fuzzy system was 41.081 (user 3) corresponding to the qualitative level or fuzzy set "Poor", while the highest level of satisfaction of the proof of concept was 79.136 (user 5) corresponding to the qualitative level or fuzzy set "Good”. Similarly, it is possible to observe that for two of the users the qualitative level "Fair” was obtained (users 1 and 2), for two of the users the level "Poor” was obtained (users 3 and 4) and for the remaining user the qualitative level "Good" was obtained (user 5). Finally, using as input to the system the averages of the inputs (*sat_pos* and *sat_sent*), the level of satisfaction for the whole test is 61.605, which corresponds to the qualitative level or fuzzy set “Fair”. From the above results, it was possible to verify the usefulness of the proposed system in terms of estimating the level of satisfaction in quantitative and qualitative terms from input values on different scales and obtained by using different methods. The levels of satisfaction per user can be seen more clearly in Figure 10.

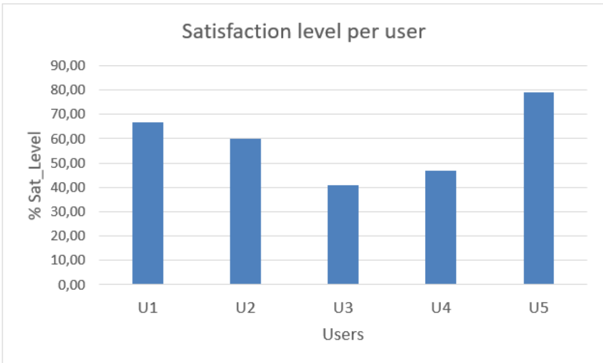

Figure 10: Satisfaction level per user of the proof of concept. (Source Own)

4 Conclusions and Future Work

Based on the challenge of improving the estimation of the satisfaction attribute in user tests, taking advantage of the benefits provided by affective computing, in this paper we propose as a contribution a system based on fuzzy logic, which allows the determination of the satisfaction attribute in usability tests by combining the conventional satisfaction level obtained from the quantitative answers of the post-test questionnaire and the satisfaction level determined by applying opinion mining and sentiment analysis techniques on the users’ opinions in the usability test. Thus, the fuzzy system has as inputs both the average of the quantitative ratings of the post-test questionnaire and the composite value of the polarities of the users’ opinions, so that from these inputs the system calculates the output satisfaction level, making use of inference rules that relate the fuzzy sets obtained from the inputs. Thus, this proposal aims to serve as a reference and contribution in academic and enterprise scenarios regarding the objective determination of the satisfaction attribute in user tests.

With respect to the traditional approach used for the determination of the satisfaction attribute in user tests, the proposal presented in this article aims not only to improve objectivity in the determination of this attribute through the application of sentiment analysis techniques, but also to obtain the level of satisfaction of test users in numerical and linguistic terms, which are more intelligible to the coordinators of usability tests. In this same sense, the application of fuzzy logic allowed the combination of input variables in different numerical scales and qualitative levels (level of satisfaction from the post-test questionnaire in the range of 0 to 5 and level of satisfaction from sentiment analysis in the range of 0 to 1) to obtain a combined level of satisfaction in the range of 0 to 100 with four qualitative levels or fuzzy sets: poor, fair, good, and excellent. Thus, the proposal presented in this article is intended to be replicated at the academic and enterprise level in terms of conducting user tests, supported by the advantages provided by affective computing and fuzzy logic.

The open technologies selected for the construction of the proposed fuzzy system proved to be suitable for the estimation of the satisfaction attribute in user tests, based on the combination of opinion mining techniques with the conventional method of determining this attribute based on perception questionnaires. Thus, for the definition of the membership functions of the inputs and output of the fuzzy system, as well as for the specification of the membership rules and the implementation of the output satisfaction level inference method, the Java JFuzzyLogic library was used. Likewise, for the processing of the files containing the data associated with the input variables of the system (questions of the post-test questionnaire and opinions of the users in the interaction), the javacsv library was used. In the same sense, for the determination of the polarities (positive, negative, and neutral) of each of the opinions of the post-test questionnaire, the VaderSentiment library was used. The technologies used in the development of the system are intended to serve as a reference to replicate the implementation of fuzzy logic-based tools focused on the study of attribute satisfaction in usability tests, as well as in other contexts in which fuzzy logic can be applied.

The proof of concept developed using the proposed fuzzy system, allowed to verify its functionality and usefulness in terms of estimating the level of satisfaction in user tests, based on the combination of sentiment analysis techniques with the traditional method of determining the satisfaction attribute. Thus, in the "proof of concept" considered, which takes as input data both the answers to 3 questions of the post-test questionnaire and the opinions associated with the interaction of 5 users, it was obtained that the lowest level of satisfaction was 41.081 with a qualitative level of "Fair", while the highest level of satisfaction was 79.136% with a qualitative level of "Good". Likewise, the level of satisfaction obtained for the entire usability test was 61.605%, which corresponds to the "Fair" qualitative level.

Finally, as a future work derived from the present research, we intend to enrich the development of the proposed system by including new input variables to the system, such as those obtained from the monitoring of physiological variables in user tests (heart rate, galvanic skin conductivity, blood pressure, facial expression, among others). This is due to the close relationship between the satisfaction attribute and emotions, as well as their multimodal nature. In the same way, it is intended to provide the system with the functionality to assign weights to the input variables, so that for the calculation of the satisfaction attribute it is possible to configure the level of influence of the affective computing methods over the traditional methods.

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Author contributions

The authors contributed equally to this work.

Conflict of interest

The authors declare no conflict of interest.

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