EVALUATION OF THE HUMAN TEXTILE SENSATION USING FUZZY LOGIC

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Abstract
The knowledge about the tactile sensation of different people is very important for the producers, especially, if they would like to develop better products, which content the customer's requirements to textile fabrics. The people just describe their feeling by touching fabrics. The first task of this work is to analyze the differences and varieties in the tactile sensation. After that, for implementation of the experimental investigation in a computer data base more mathematical, "non verbal" method for the description of the information about the tactile sensation is required. This work is a step in the developing the fuzzy logic system for evaluation of the data from the verbal statements of the testing persons. In this study, 200 students tested two different fabrics and rated them on a scale from 1 for "not recognizable" to 6 for "high intense recognizable" for 24 different attributes. The panel was carried out behind a special test box, where the person couldn`t rate the fabrics visual; only by touching. At the second stage, smaller groups of about 20 humans tested different samples, for which the main mechanical properties using the KAWABATA system will be determined, but here only the thickness will be discussed. With principal component analysis the main attributes are selected and the groups of the similar attributes are found. Fuzzy and intuitionistic fuzzy membership functions for the description of these attributes are proposed and compared.
Key words: tactile sensation, woven structures, thickness, fuzzy logic

1. Introduction

The knowledge about the tactile sensation of different people is very important for the producers, especially, if they would like to develop better products, which content the customer's requirements to textile fabrics. The people just describe their feeling by touching fabrics. The first task of this work is to analyze the differences and varieties in the tactile sensation, in order to get information about the reproducibility and accuracy of the testing method and testing persons. First results from this task are reported in [1]. The next, current task is to mathematize the verbal statements about tactile sensation using fuzzy logic in order to build an expert system in this area.
In order to analyze the differences in the tactile sensation, a testing panel for subjective testing was arranged. The methodology of the experiment is described in the section "Testing Method". After that, results from principal component analysis for one sample are presented, where the main linguistic variables are selected. At the last point first steps in the definition of the fuzzy membership functions are described.

2. Testing method

At this first stage of the study, 200 students tested two different fabrics and rated them on a scale from 1 for "not recognizable" to 6 for "high intense recognizable" for 24 different attributes. The panel was carried out behind a special test box (Fig.1), similar to the reported one in [2, 3], where the person couldn`t rate the fabrics visual; only by touching. Every evaluator had 20 minutes left to test.
The investigation of the accuracy of the method, reported in [1] shows, that about 70% of all persons are able to recognize differences in the samples and can make reproducible results. At the same time the deviations in the evaluations of the samples differs significantly. Definitive correlation between the tactile sensation and the connected objective measured parameter

were found, but the correlation coefficients were seldom higher then 0.6 because large deviations of the evaluations were found.

Figure 1. Test box

At the second stage of the investigation 16 woven fabrics, used currently in the clothing production, but with different properties (from very thin to very thick, from very soft to very hard etc) were tested, so that every sample type was tested by ca. 20 persons. The purpose of this test is to investigate the sensitivity of the testers and to build groups of the important words (linguistic terms in German language) for characterisation of the sample properties. Even some single investigations in the area exist for instance [4,5] and several works about the KAWABATA System exists as well, in Germany and Europe such measurement still are done separately (subjective and objective evaluation of the fabric handle) and one of the goal of this work is to be a step in the next development in this direction.

3. Linguistic terms an principle component analysis

Between the values for the investigated terms together with some of the values of the objective measurement (for instance thickness) were investigated using the principal component analysis. The main directions on the Fig. 2 can be recognized to be “thin-thick” and “hard-soft”. The correlation analysis demonstrates that between “Thick” and “Thin” is a negative correlation as expected, and between the measured “Thickness” and the subjectively evaluated attribute “Thick” is a very high correlation.
Since all other properties are more complex and connected with more investigation, here the first relation “thin-thick” will be investigated.

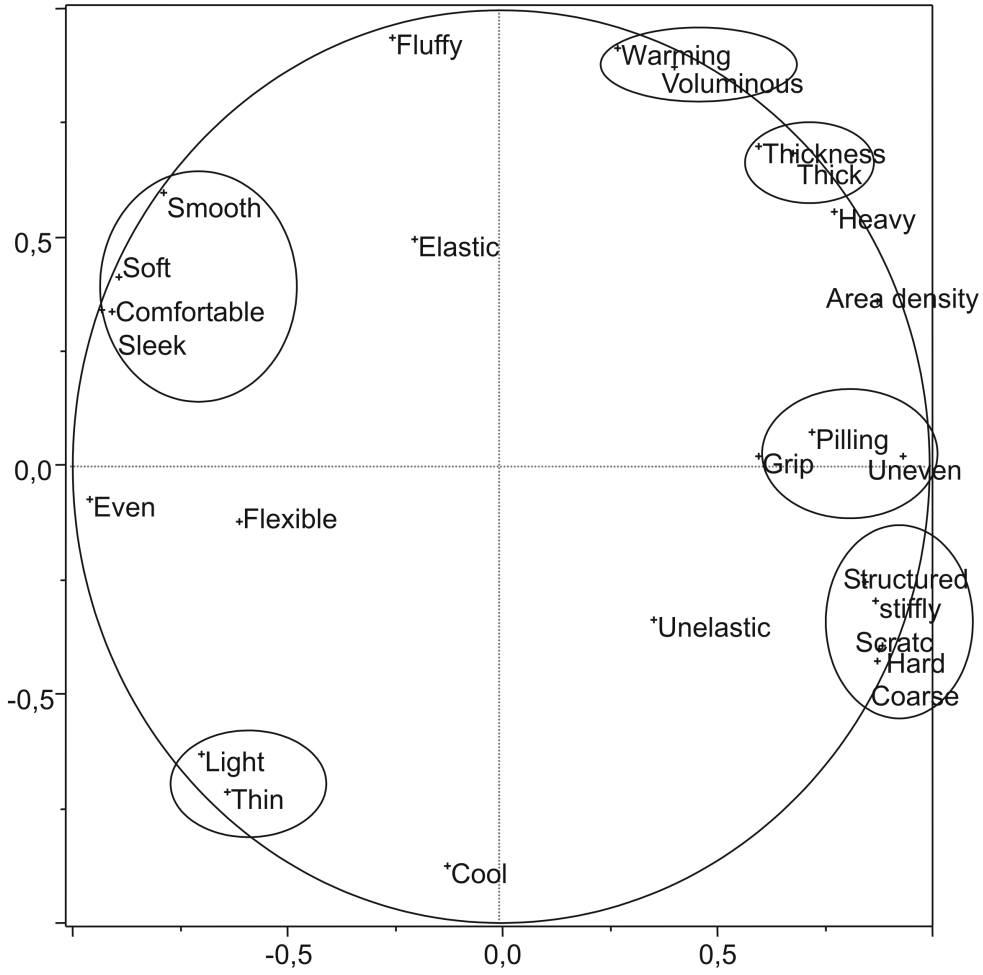

Figure 2. Correlation circle

4. Comparison between the objective and subjective evaluation for the thickness

Several geometrical and mechanical parameters of the fabrics were measured, but in this paper only the results from the thickness will be presented. Fig.3 presents in the horizontal axis the measured thickness of the fabrics according the norm and in the vertical axis – the verbal statement, selected from the persons for each sample. The samples with 0.4 and 0.6 mm thickness were tested by all 198 persons (their circles are thicker); all other only by 20 persons. The radius of the circles are proportional to the percentage of the people, selected the same evaluation for the given sample. From Fig. 3 is very clear, that the samples, thinner than 0,4mm are definitively found as thin, and the samples thicker than about 1,5 mm are found and filled as definitely thick. The range between these two values is the range, where the most woven samples for clothing are produced. In order to present this area more clear, the logarithmic scale was used in the thickness axis. For this middle range between 0,4 and 1,5 mm there is some trend in the subjective evaluation, which correlate with the objective measurement, but the deviations around this values are very large. This means, that by direct feeling (without comparison between samples!) more then 2/3 of the people can not determine the exact thickness of the fabrics in this range. This can mean as well, that for some people for instance 1,5 mm is too thick, where this is still a thin fabric for other people. Because of this there are large deviations in the values of this range.

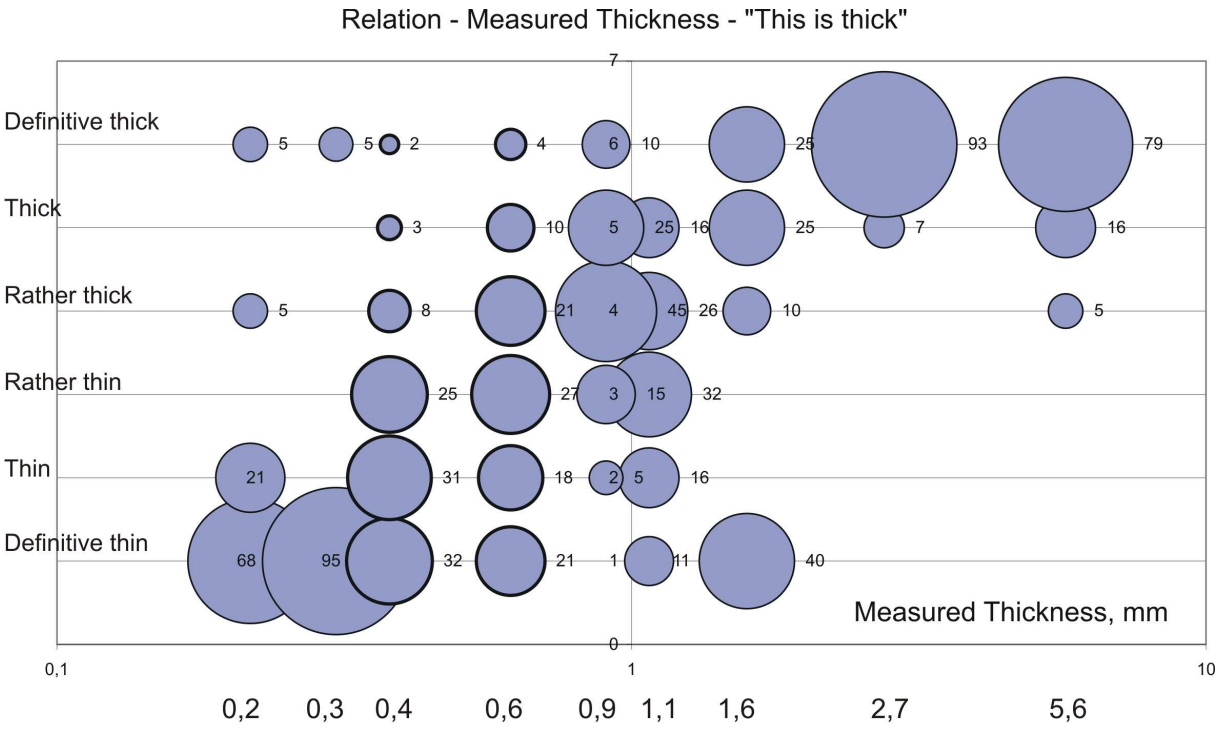

Figure 3. Dependancy between the measured thickness and subjective feeling about „thick„

5. Fuzzy membership functions

In order to be able to implement the data of the tactile sensation in an expert system, it has to be stored in the computer in some mathematical or descriptive way. A suitable tool for the normalisation of the verbal statements is the fuzzy logic.

The fuzzy logic can be considered as an extension of the classical crisp logic, because except the values of “true” and “false” (or “A is member of B“ and “A is NOT member of B”) values between these are allowed. If the false is marked with 0, true with 1, then some sentences can belong to the set of the true sentences with membership degree of 0.2. This means that this sentence is almost false, but in some cases or under some conditions can be “slightly true”.

For the translation between objective values (thickness 0.6mm) and linguistic terms (this fabric is very thin) membership functions are used [6]. In our case we selected the simplest one – trapezoidal functions and tried to fit them to the results of the Fig. 3. Different linguistic terms can be used, but in this case it seems logically to be like following:

Very thin
Thin
Between thin and thick
Thick
Very thick

The exact limits and form of the membership functions will be subjected in a separate investigation; here it is more important to be defined if this classification and definition of 5 terms could be suitable. Remembering the comment in the previous section, that the middle has very large deviations, it will be clear, that with the three so defined variables “thin”, “between thin and thick” and “thick” the work will be difficult, because of the lower accuracy of the information stored in this variables. For this reason a special extension of the fuzzy

logic, intuitionistic logic seems to be more appropriate for coding the experimental data in the computer.

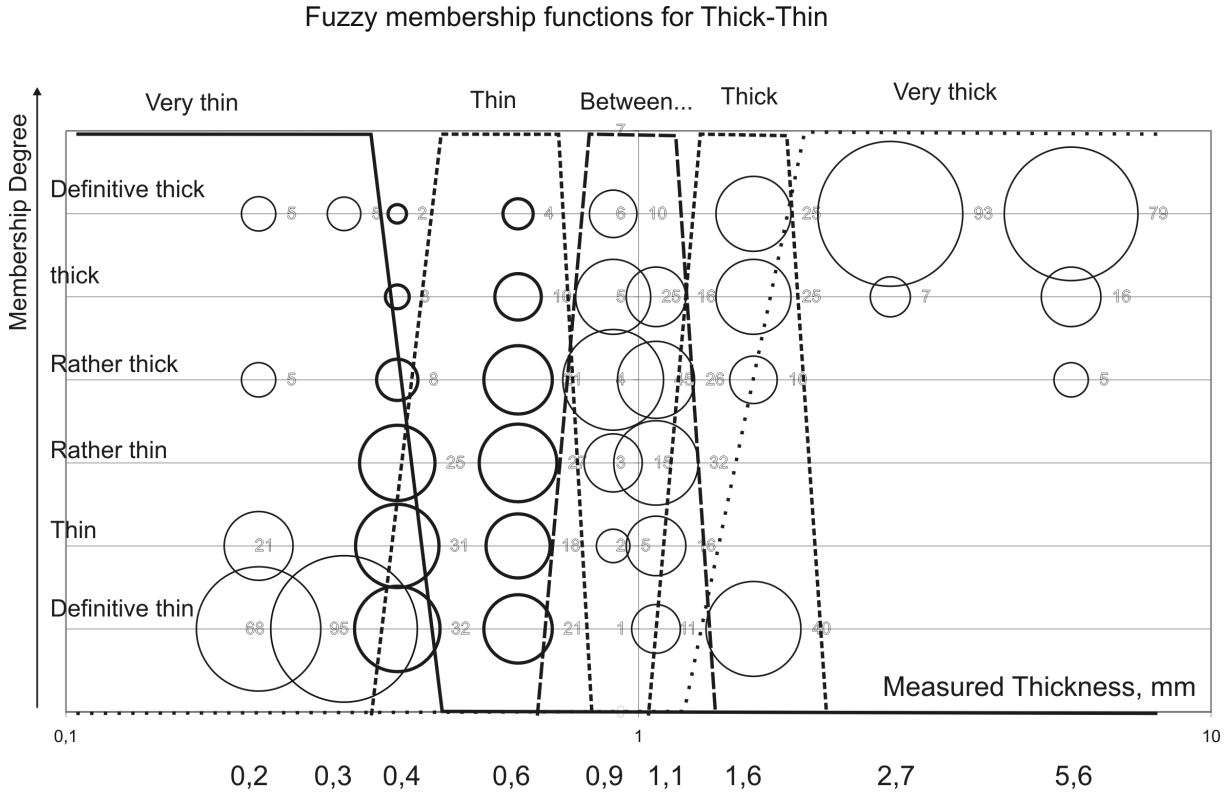

Figure 4. Fuzzy logic membership functions about the thickness evaluation of the fabrics

6. Intuitionistic fuzzy membership functions

The intuitionistic logic is an extension of the fuzzy logic [7], which works with two memberships instead of one, like the fuzzy logic. To each intuitionistic variable are corresponding two independent linguistic variables, with relevant "membership" functions:

Membership function $\mu(x_1)$ - "the fabrics is thick"

Non-membership function $v(x_1)$ - "the fabrics is NOT thick", where

$$0 \le \mu(x_1) + v(x_1) \le 1 \qquad (1)$$

A third, dependent on the both functions, function $\pi(x_1)$ can be introduced - "the fabrics is neider thin, nor thick", so that

$$\mu(x_1) + v(x_1) + \pi(x_1) = 1 \qquad (2)$$

Actually, the linguistic variable should be named "normal or usual thickness", but then is difficult to make relation between membership and non-membership degrees and the application variables, and is more difficult to work with the negation "not normal" fabrics. Because of (2). This function is named in some works as degree of non-uncertainty

$$\pi(x_1) = 1 - \mu(x_1) - \nu(x_1) \tag{3}$$

Using these ideas, for the evaluation of the thickness “Fabric is thick” is defined as presented on the Fig. 5. The non-membership function in this case will be “The fabric is NOT Thick” = “The fabric is thin”.

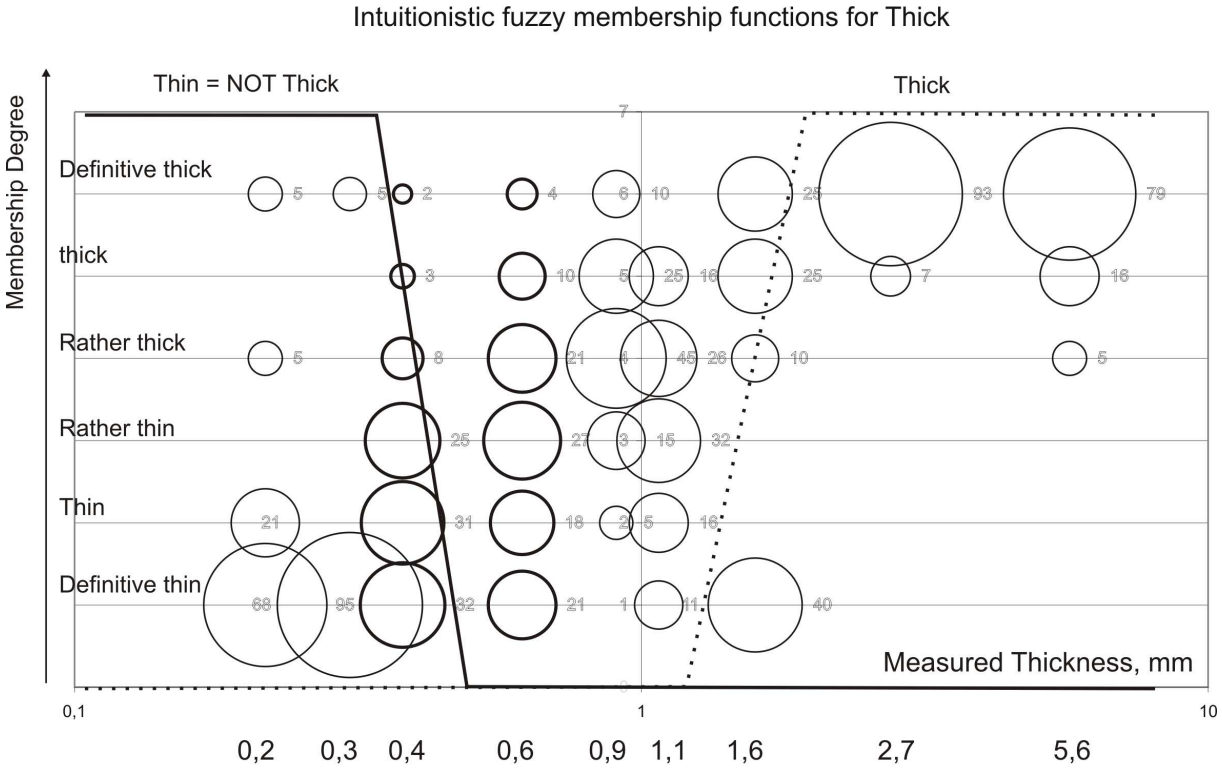

Figure 5. Intuitionistic fuzzy membership functions for « Thick »

This allows coding of the evaluation into the computer as for instance fabrics with thickness of 1,3mm according Fig. 5:

Will have membership degree ca. 0.15 for “Fabric is thick”

Non-membership degree 0 “Fabric is thin”

and non-uncertainty degree of 0,75, which means, that in the most cases such fabrics will be evaluated in the range between thin and thick.

As mentioned, the exact form of the membership functions is subject research in progress and will be reported separately.

The intuitionistic fuzzy logic integrates more information into one variable, using the membership, non-membership and non-uncertainty degrees. In the case of the fabrics´ thickness this could be suitable and enough accurate way to model the data. Actually, if the sensitivity of the humans for some of the other investigated parameters like softness, flexibility etc. is higher, this will be not enough accurate. In this case probably the “normal” fuzzy logic with more variables will be more suitable and more flexible for working with more linguistic variables for one and the same parameter. Final decision about this can be taken after all important physical parameter of the samples are investigated.

7. Conclusion

An experimental investigation of the tactile sensation of the humans for woven structures is presented. Using the principal component analysis, the most important independent parameters for the fabric evaluation are selected. For one of them – the fabrics thickness, the comparison between the objective measured thickness of 9 samples and their evaluation from humans is presented. It is found, that the humans identify the fabrics, thinner than 0.5mm as "thin" and thicker than 1.5mm as "thick", but in the range between these two values, very large variations in the evaluations are determined. The fuzzy logic membership functions can be used for coding the relation between the objective value and the tactile sensation, but the use of 5 membership functions (as grades for the thickness) seems to be difficult, because of the large deviation in the middle range. Because of this, the intuitionistic membership functions are proposed for storing the data. This integrates the entire information for the "thick" and "not thick" and "NOT thick and NOT thin" in one variable with three degrees, which is enough for the case of "thickness". It is not clear if such coarse scale will be suitable for working with the other properties of fabrics, where potentially higher sensitivity of the humans could be expected.

8. Acknowledgement

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9. References

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