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Topographic modelling of haptic properties of tissue products

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Abstract. The way a product or material feels when touched, haptics, has been shown to be a property that plays an important role when consumers determine the quality of products For tissue products in constant touch with the skin, softness" becomes a primary quality parameter.   In the present work, the relationship between topography and the feeling of the surface has been investigated for commercial tissues with varying degree of texture from the low textured crepe tissue to the highly textured embossed- and air-dried tissue products.   A trained sensory panel at was used to grade perceived haptic "roughness".

The technique used to characterize the topography was Digital light projection (DLP) technique, By the use of multivariate statistics, strong correlations between perceived roughness and topography were found with predictability of above 90 percent even though highly textured products were included. Characterization was made using areal ISO 25178-2 topography parameters in combination with non-contacting topography measurement. The best prediction ability was obtained when combining haptic properties with the topography parameters auto-correlation length (Sal), peak material volume (Vmp), core roughness depth (Sk) and the maximum height of the surface (Sz).

1. Introduction

For tissue products touch and tactile sense is the most important factor used to judge the overall consumer acceptance [1, 2].   For different types of tissue products the significance of the tactile sense varies. A tissue product can be judged in many different ways by the tactile sense, but the outcome usually is depicted either as the bulk feel or as the surface feel. The present work has been focused on the surface feel [3]. The surface feel stands for about 70 percent for facial tissue, 50 percent for toilet paper and 30 percent for household paper of the overall consumer acceptance.

The human structure sensitivity is extremely good. The hand and face are the parts of the body with the best structure sensitivity, especially the fingertips and the lips. The tactile sense is better in discriminating between different feature heights than widths. Height has a threshold of around $1\,\mu$ m compared to widths of around $10\,\mu$ m. Also, it is much easier to detect small features during movement - either of the sample or of the body part. From static "non-movement" detection only structures greater than $100\,\mu$ m can be detected. [4]

The cells and units which are involved in the tactile sense of the skin are called mechanoreceptors. The receptors can be divided into three sub-groups; intensity receptors, rate receptors and acceleration receptors. [5] Many nerve endings can originate from the same nerve cell. They are distributed randomly

unlike the Meissner corpuscles and the Merkel discs. These nerve endings associate with the sensations of warmth, coolness, pain, tickling and itching. [6].   How a product feels when touched, contributes substantially to the consumers' overall acceptance or preference of paper and fabric products. The overall sense can be divided into several under groups, which all can be characterized using trained human panels [1, 2].   Paper products can be found in a wide range of areas, from newspaper to juice packet, to furniture cardboards, to toilet paper, to napkins, etc. All papers consist of a fiber network and in almost all cases plant fibers are used. There are three main types, writing paper, cardboard and tissue paper. In this study the focus is on tissue products. All paper types are constructed in a similar manner. The main differences are type and the amount of fiber used and which additives used. For tissue products there are five basic production stages: Pulping, stock preparation, sheet formation, drying, and creping. Embossing is a converting process with purpose to binding two sheets together, improve the visual appearance, increase bulk, increase bulk softness, improve haptics and improve abrasive properties (paper to paper or against some other surface). Embossing usually increase the thickness of the paper several 100 percents in commercialized products.

2.   Methods and materials
2.1   Digital Light Projection
A digital light projection (DLP) system GFM[1] MicroCAD **[7]** with a horizontal- and vertical resolutions (x,y,z) of 16um, 16.2um and 2.6um respectively was used to measure the areal (3D) topography. MountainsMap Premium 4.1 software from DigitalSurf[2] was used for all topography analysis.

2.2.   Tissue samples
From each product three different sheets of paper and two different places per sheet were measured, with a measuring area of 26mm*20mm (see figure 1).   The samples were placed under a glass plate with a weight of 256g and area of 10*10cm to avoid wrinkles and to keep the sample still during the measurement.   Two sets of 6 commercial tissue samples (the calibration and the verification sets) where used to firstly initially identify the significant properties influencing the haptic "roughness" on the first set of six samples and secondly to verify the results on the 2'nd set, the verification set.   The samples had a large parameter variation of drying method, no. of ply's (sheet layers), thickness, embossing and fiber type.   The finer fibre structure visual in the SEM pictures refer to the "fuzziness" of the tissue is not considered in this study but is besides haptic "roughness" also an important feature of the tissue products.

2.3.   Topography characterization
23 Field parameters **[8]** (Sa, Sq, St, Sz, Ssk, Sku, Sk, Spk, Svk, Sr1, Sr2 , Sdq, Ssc, Sdr, Sds, Str, Sal, Sdc, Smr, Vmp, Vmc , Vvc , Vvv) from the ISO 25178-2:2012 standard on "areal topography" parameter definitions was used to extract a set of significant height- (Sz –maximum height), spatial- (Sal-auto-correlation length), functional- (Sk-core roughness depth, Vmp-material volume of peaks) topography parameters.

The trained sensory panel was used to grade the products perceived haptic "roughness" in a haptic scale rank from 0-100.

Statistical Methods
Multi linear regression (MLR), complemented with principal component analyze (PCA) and partial least square regression (PLS) where used to construct the models explaining the influence of the surface properties to the perceived haptic "roughness" **[9, 10]**.

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[1] GFMesstechnik, Berlin, Germany, http://www.gfm3d.com

[2] Digital Surf, Besançon, France, http://www.digitalsurf.fr
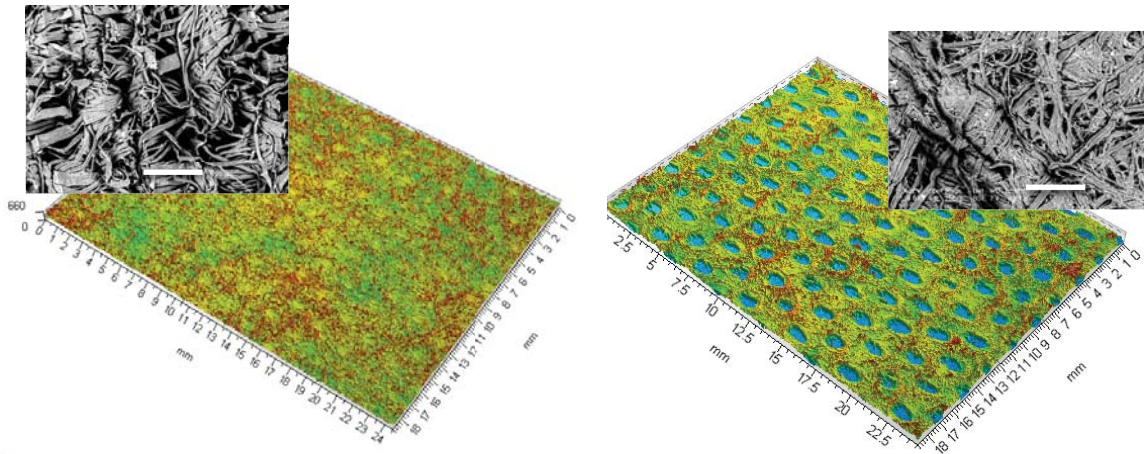
Figure 1. Optically DLP measured 24*19mm examples of two of the tissue producs   used in this study. Sample I1 (left) is a facial tissue product with a very smooth surface while I6 (right) is an embossed product with larger surface structures.   The smaller pictures are 800*600um SEM measurements displaying the detailed fibre structure.

3. Results

3.1 Material Ratio and material distribution

Material ratio for different depths in a surface can be plotted in "Abbot-Firestone-" or "bearing area" diagram as a "finger print" of the material distribution in a product (figure 2).   The Sk parameter in ISO 25178-2:2012 tries to extract the rate of increase of material ratio in the "top- or bearing areas" (see arrows in figure 2) of the surface and is in this study used to quantify the material distribution in the upper region of the surface expressed as the height in um of the top region where the human finger and senses meet the paper.

Figure 2. The Material Ratio Curves measured for product I1 (left) and I6 (right) of the calibration set. The steep part of the slope is significantly steeper (high Sk value) for I6 than for I1 (lower Sk-value) indicating a concentration of material distribution in the upper region of the surfaces.

3.2   Calibration set analyze

All the topography parameters were analyzed by studying mean values for measurements of the sheets in combination with the human panel sensory observations of the "perceived roughness".   In figure 3 (left) below, it can be seen how a complete set of ISO 25178-2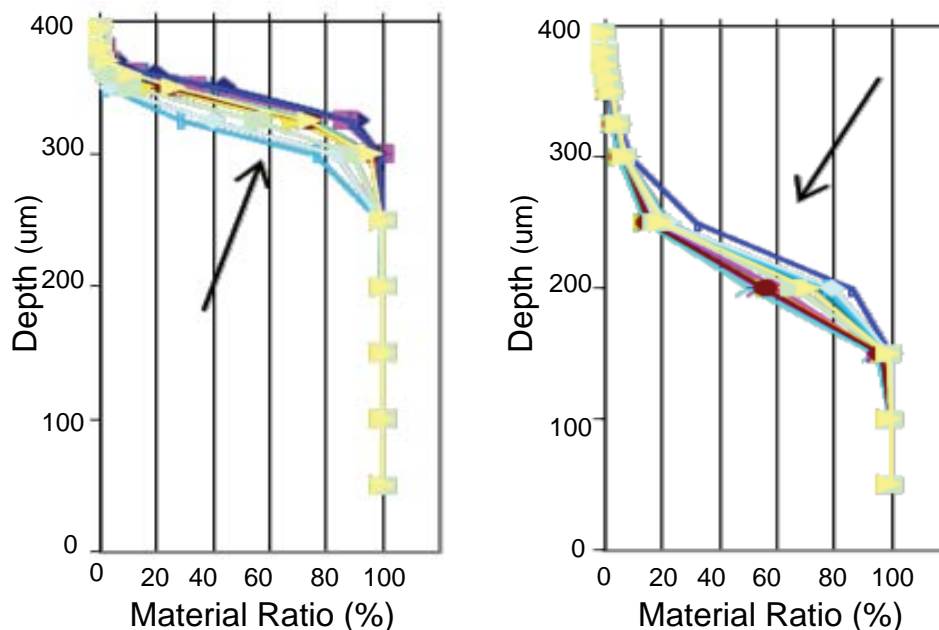:2012 parameters contribute to explain the "perceived roughness" forming the circular pattern.   By extracting a minimum set of parameters with relatively high "loading" values for the two principal components in the diagrams (PC1 and PC2) like in figure 3 (right) a numerical model describing the "perceived roughness" as a function of the chosen parameter set can be formulated like in equation (1) below.

Numerical regression models based on only topography parameters ended up with low R2-values A "product type" parameter, DL, distinguishing between multiply and singleply product types (DL: -1 or1), had to be added in order to achieve models with higher R^2-values than 0.77.   DL together with the topography parameters Sk, Vmp, Sz and Sal, create models explaining the haptic "roughness" with a high prediction ability (R^2-values around 0.98).

Figure 3.   Left: Principal component loading plot using the complete set of topography parameters. Right: A loading plot with the selected parameters DL, -Sk, Sz, Vmp, Sal with PCs explaining in total 96 percent of the variability in haptic "roughness".

When the mechanical parameters tension stiffness index and tension stretch index were added into the numerical regression models the R^2-value increased insignificantly but the robustness in prediction improved by removing unwanted trends in the pattern of residuals.

A positive regression coefficient (figure   4 left) implies that with increasing value for the parameter that the surface will feel "rougher", the negative regression of the –Sk parameter in figure   4 below indicate a positive influence on haptic "roughness" of increasing Sk.

Figure 4. Left: Normalized regression coefficients for the PLS modelling with mechanical parameters included. Right: MLR model of the calibration set using the DL-, and the topography parameters here resulting in a R^2 of 0.98.

3.3 Validation Set analysis
The validation set evaluation was based on the parameters DL, Vmp, Sal, Sk, Stiff, Stretch and Sz, obtained from the calibration set evaluation.

If only topography parameters were used a regression model with R^2-value of 0.77 was obtained for the validation set.   When DL and mechanical properties where included the R^2-value increased to 0.97. These strong correlations where achieved when topography parameters Sz, Vmp, Sk, Sal, were completed with the mechanical properties Stiffness index and Stretching index along with DL and resulted in the numerical model in eq. 1 below.   Constants A to H where given by the PLS evaluation using the validation set surface measurement values in combination with the human panels' evaluation of the haptic "roughness".

   "perceived haptic roughness" = A+B*-***DL***+C*Vmp+D*Sal+E*(Sk)+F* ***Stiff***+ G*-***Stretch*** H*-***Sz***   (1)

From equation 1,   DL, Sz, and Stretch had negative regression coefficient values, which imply that an increase in the parameter value results in a decrease in perceived haptic "roughness". The coefficients for Vmp, Sk and Sal were positive, hence positive correlated with the haptic "roughness".

3.4 Optimization example of Haptic Property
With help of results from the above regression it is possible to optimize the roughness feel for a product. Product 4 in the validation set is toilet paper product with an embossed pattern.

   The mean haptic "roughness" for the front side was 67 and 82 for the back side on the 0 – 100 scale. The haptic "roughness" for product 4 is about the same as the mean of all the products in the validation test and to increase customer satisfaction and to lower the haptic "roughness" eq.1 above and table 1 below present a number of options for the product developers at SCA. Comparing topography values for product 4 compared to the "mean for all products", the Sal parameter stands out as a candidate for design changes.

   A decrease of Sal would according to eq. 1 be one effective way of improve the haptic feeling for the product and decreasing the "rough" feeling.   A decreased Sal would in practice result in a reduction of long wave-length components, i.e the repeating pattern around 1mm size (based on the Sal 822um and 762um in table 1).

Table 1. *Top:* Max-, min-, and mean parameter values for all measurements. *Down:* Top: Max-, min-, and mean parameter values for product 4 for both the back side and front side measurements.

		Haptic Roughness	min. Sk	Sal	Vmp	Sz	"Stiffness"	Stretch
			(um)	(um)	(um3/um2)	(um)	(Nm/g)	(%)
All Products	*Max*	90	361	1512	807	2360	0,31	14
	Min	15	22	0,52	1	125	0,05	9
	Mean	60	47	170	170	445	0,15	12
Product 4	*Front side*	63	44	822	0,74	449	0,06	13,2
	Back side	82	58	762	9,38	433	0,06	13,2

4. Conclusions
- Topography plays a significant role in explaining the perceived haptic "roughness" of tissue products.
- Topography combined with mechanical properties can predict haptic "roughness" with more than 90 percents accuracy.
- The areal topography parameters *autocorrelation length* (Sal)-most important, *maximum height* (Sz), *core height* (Sk) and *peak volume* (Vmp) all show significant impact on haptic "roughness".
- Models for optimisation of haptic "roughness" can be designed using PCA, PLS, and MVA methods.
- Non-contact areal metrology using structured light capture the significant topography responsible for the haptic "feeling of "roughness of tissue products.

5. Future

The models of the haptic "roughness" will be further developed by the investigation of the contact pressure and material properties influence as well as the extension towards using areal topography metrology to quantify the "fuzziness" of the tissue products and relations to the haptic "roughness" and the customers total "feeling" for the tissue products.

Acknowledgement

References

[1]   Civille D 1990 Development of Terminology to Describe the Handfeel Properties of Paper and Fabrics *J. Sensory Studies* **5** 19-32

[2] Meilgaard M C Civille G and Carr B T 2007 *Sensory Evaluation Techniques* London CRC Press, 4th edition

[3] Hollmark H 1983 Evaluation of Tissue Paper Softness, *Tappi J.* Feb.

[4] Berland C 2006 *Skin Sensitivity to Texture* SCA Report F3589

[5] Lamb Determination of Softness of Tissue Products München 3rd PTS Tissue Symposium

[6] Tortora G J and Reynolds Grabowski S 2004 Introduction to the Human Body USA John Wiley & sons

[7] Chen L C and Liao C C 2005 Calibration of 3D surface profilometry using digital fringe projection *Meas. Sci. Technol.* **16** 1554–1566

[8] Jiang X Scott P J, Whitehouse D J and Blunt L 2007 Paradigm shifts in surface metrology Part II The current shift *Proc. R. Soc.* **A 463/2085** 2071-2099

[9] Altman D G 1994 *Practical Statistics for Medical Research* London Chapman & Hall 1st edition

[10] Esbensen K H 1994 Multivariate Data Analysis – in practice Oslo CAMO Software AS 5th edition