Fingertip friction and tactile perception on randomly rough surfaces

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Most everyday surfaces are randomly rough on sufficiently small scales. We investigated fingertip friction and tactile perception of randomly rough surfaces using 3D-printed samples. The interaction between surface asperities and fingertip skin led to higher friction for higher microscale roughness. Individual friction data form the basis of a psychometric curve which relates decisions on perceived similarity to differences in friction. Participants noticed differences in the friction coefficient as small as 0.035 for samples with friction coefficients between 0.34 and 0.45. Tactile perception of similarity between surfaces was dominated by the statistical micro-scale roughness rather than by their topographic resemblance.

Keywords (from 3 to 5 max): skin friction, haptics, tactile perception, surface roughness, Hurst exponent

1. Methods

1.1. Samples

Randomly rough surfaces were defined by an algorithm [1] and nine samples produced by 3D printing. Each three samples had the same topography, i.e. the same spatial distribution of hills and valleys, or the same Hurst exponent, which describes the power law decay of roughness towards small length scales.

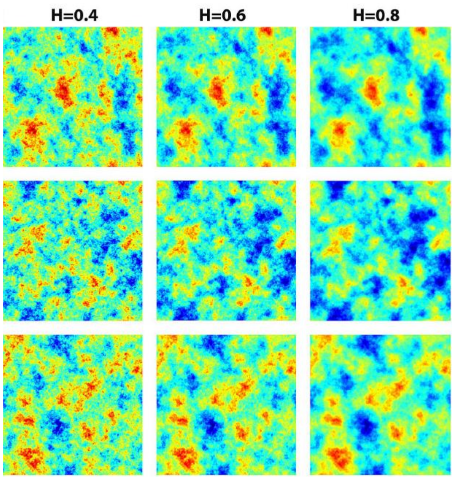

Figure 1: Color representation of the nine surfaces.

1.2. Haptics experiments

Thirteen participants explored the samples by sliding their fingertips in circles over the surfaces. Normal and friction forces were recorded, and participants were asked to judge the perceived similarity between samples. The judgements were analyzed by multidimensional scaling analysis in order to identify dimensions of tactile perception and related them to surface parameters.

1.3. Results

Fingertip friction forces increased with surface curvature for these samples [2]. The surface curvature is dominated by structures at small length scales, and thus the friction increased with increasing microscale roughness. Friction played an important role in the tactile perception of similarity. The smaller the difference in friction coefficient, the higher was the probability that participants judged surface as more similar (Figure 2).

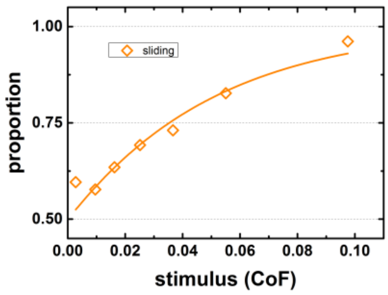

Figure 2: Proportion of decisions which judge that sample as being more similar to a reference which has the smaller difference in friction. The stimulus intensity is the difference in friction coefficient between samples with respect to the reference (adapted from Ref. [2]).

2. Discussion

The increase of friction with microscale roughness reveals that the deformation contribution dominates the adhesive contribution due to interaction of roughness asperities with the viscoelastic skin. Three results confirm that friction is a relevant tactile dimension: Peculiar characteristics of the dependence of friction on the surface curvature are also observed in the statistical analysis of perceived similarity. A smooth psychometric function could be constructed for the friction-based stimulus intensity (Fig. 2). Finally, the topography does not play any significant role in similarity perception with the sliding fingertip.

3. References

[1] Müser, M. H. et al. Meeting the contact-mechanics challenge. Tribol. Lett. 65, 118 (2017).

[2] R. Sahli et al., Tactile perception of randomly rough surfaces. Scientific Reports (2020) 10:15800