Haptic Perception for Surface Geometry, Texture and Friction

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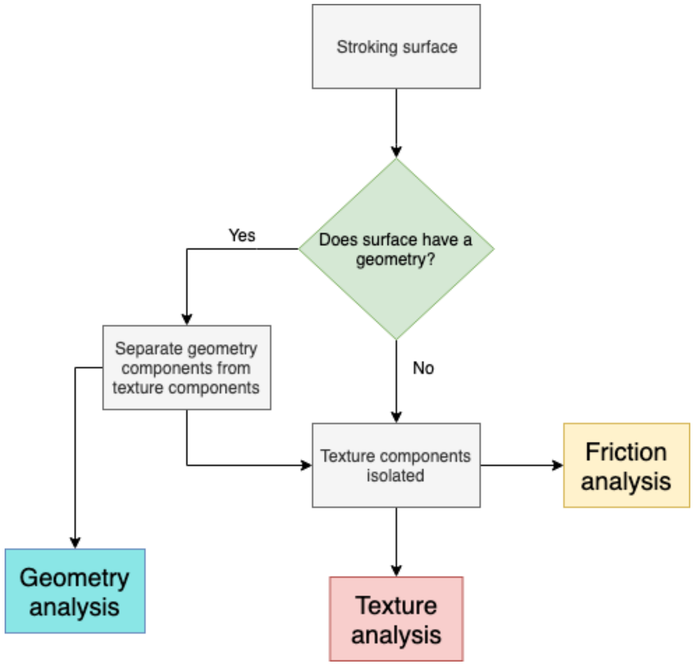
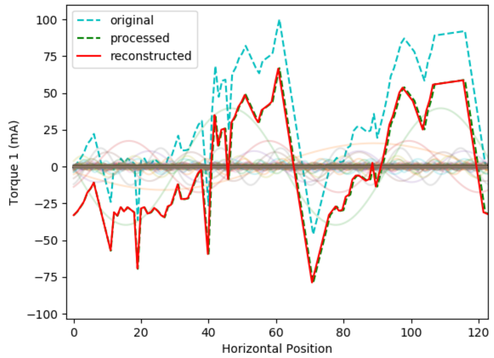
Introduction

One of the primary ways of identifying a surface is by stroking it to see how rough or smooth or coarse it is (*texture*), whether it is flat or wavy or has another pattern (*geometry*), and how slippery it is (*friction*). We made a model that can, within one stroke, discriminate between each of those 3 overlapping features, and then identify them separately.



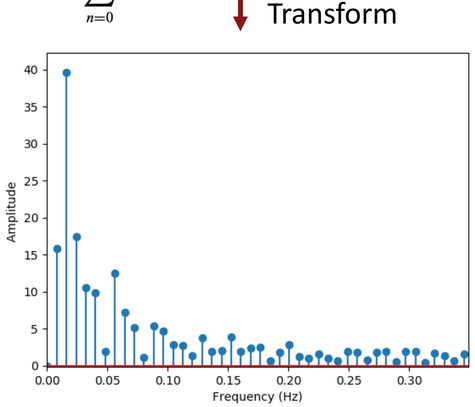
Geometry Analysis

Separating geometry from texture to analyze them separately

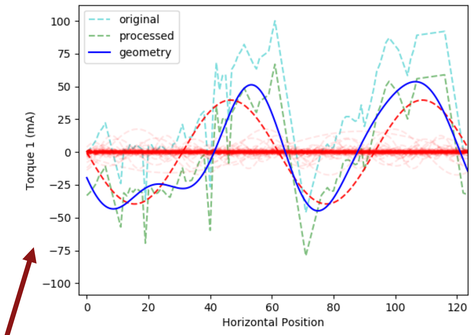


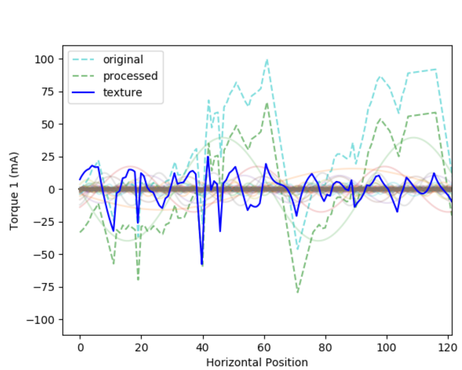
$$A_k = \sum_{n=0}^{N-1} e^{-i\frac{2\pi}{N}kn} a_n$$

Fast Fourier Transform



Inverse Fourier Transform





Texture Analysis

Comparing standard deviations of torque readings obtained during stroking

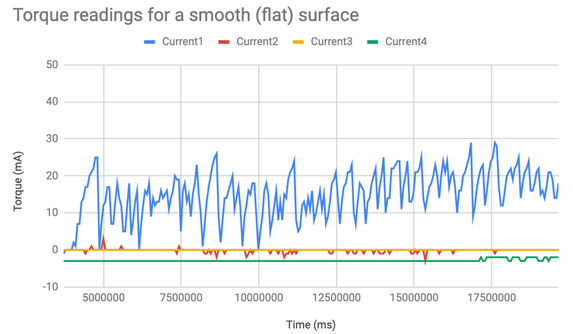


Fig 1A (s.d1 = 6.79, s.d2 = 0.89, s.d3 = 0)

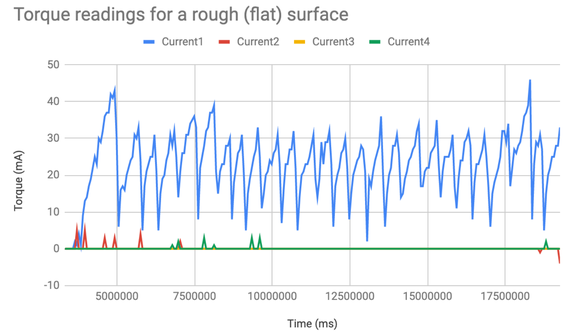
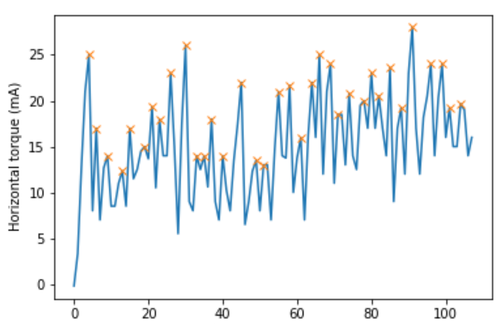


Fig 1B (s.d1 = 8.81, s.d2 = 0.64, s.d3 = 0)

Friction analysis

Calculating friction coefficient

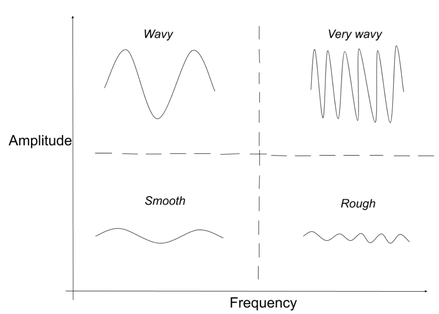


F_H = Horizontal force
= Average of the peak heights

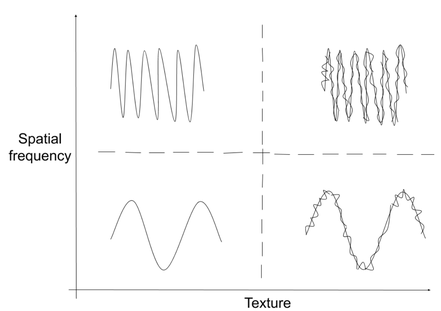
F_V = Normal contact force

μ = Friction coefficient
= F_H / F_V

Discussion



Geometry can be considered high amplitude texture



Range of all possible combinations of texture and geometry in a surface

Conclusion

- Machine learning models (KNN and multinomial logistic regression) can accurately classify surfaces using amplitude and frequency of their characteristic waves, and standard deviations of the torque readings as predictors.
- Future models could be made to predict the exact geometry using the position scan obtained already from stroking.
- It is also worth investigating how friction affects texture, or vice versa.