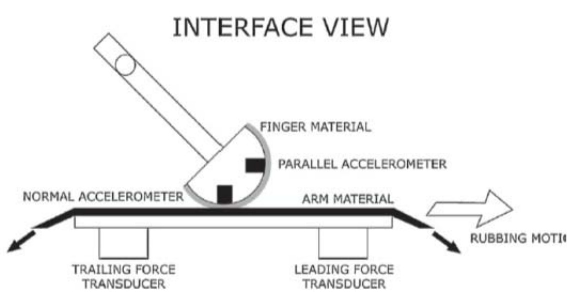
ACOUSTICS OF FRICTION UNDER LIGHT LOADS FP7-PEOPLE-2009-RG

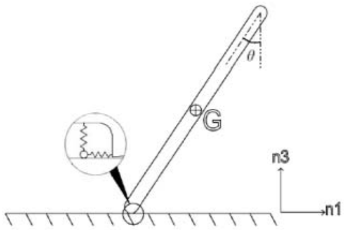
Summary Report

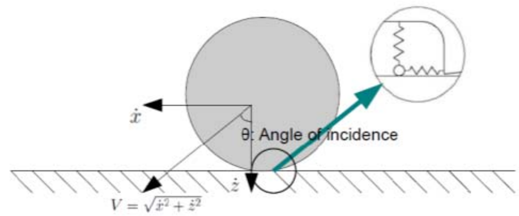
The primary objective of this project is to relate tribological characteristics of soft material surfaces to sound and vibration that results from the sliding contact of surfaces against each other under light loads. Establishing a firm relationship between characteristics such as surface roughness, adhesion, geometry, and material properties to the acoustic response that results from their rubbing against each other will assist in advancing a number of technologies by providing modeling capabilities for tactile sensing, feedback control in haptics applications, and characterization of surface qualities of materials and effects of cosmetics on skin.

In tactile sensing, as the skin comes into contact with a surface, the contour and roughness of the surface together act as forcing functions and excite the mechanoreceptors under the dermis. Further, the adhesive components contribute tension to the excitation forces. To emulate tactile conditions a new set up was design to make friction measurements under very light loads, as shown in the figure. This new apparatus measures friction simultaneously with dynamic quantities such as accelerations, forces, and sound pressures resulting from a light contact over a soft material. The goal is to emulate friction finger lightly rubbing over a soft material. Here a simple, very light-weight pendulum acts like a finger and a beam that rotates about a vertical axis slides under the finger to provide the "touch." The contact force during the sliding is controlled by a lift mechanism inserted to the "finger" pendulum that can provide a lift force to it to adjust the contact force to any desirable level.



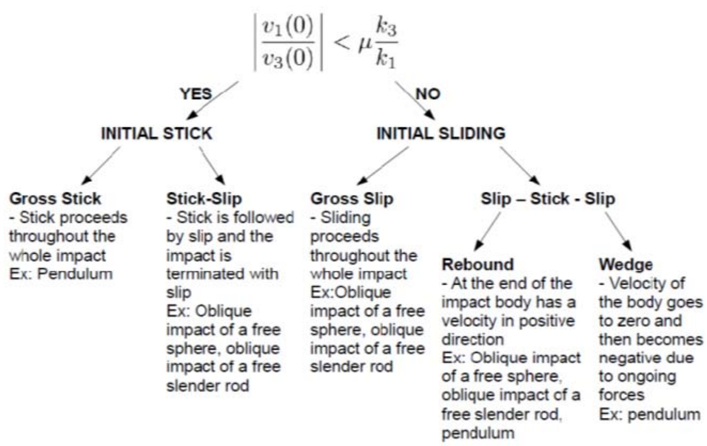
High-speed video recordings of the pendulum as contact is initiated and during sliding dynamic response showed unexpected dynamic response of the pendulum; it lifts off the surface due to a lift force induced by the friction that develops between the surfaces as a result of the angle of pendulum and the horizontal surface. Observations showed that the lift force is directly related to friction and that the amount of lift of the pendulum (finger) tip can be related to friction. Such a relationship is viewed to have the potential to make friction force measurements easily and accurately. Since friction measurements under light loads are difficult, this result is thought to be a significant contribution.
This discovery led us to pursue the dynamics of a pendulum in order to establish definitive relationships between friction and pendulum response while also considering other material properties of the finger and the surface.
Pendulum motion, as used here, is constrained and involves discontinuous contacts. In addition, because of friction nonlinear responses as wedging, jamming, swerving, pendulum may behave differently than intended.





The results produced conditions to avoid wedging (lock-in) so that friction can be related to lift easily. The basic design criterion can be summarized in terms of a critical angle that can be calculated for a given pendulum system.

Described in the above figures schematically, the compliant contact between the fingertip and surface is modelled with linear springs, also considering friction between them. Dynamic response equations are developed and solved for different conditions, as outlined below.



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The results also showed that the measurement setup is capable of separating adhesive component of friction from the overall friction force, which we believe form the basis for tactile sensing in terms of physical aspects contact.

In conclusion, in the new measurement method that has been developed for friction under very light normal force conditions, showed the dynamic response of the haptic finger directly relates to friction, in particular adhesion between the haptic finger and the surface over which it travels. Dynamic analysis of a constrained pendulum representing the haptic finger establishes such relations ships and also provides design guidelines to avoid wedging or lock-in of the pendulum tip with the compliant surface.

http://me.bilkent.edu.tr/?page_id=912&nvaf_id=11&lang=en