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Bilsay Sümer

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Influence of Preload Control on Friction Force Measurement of Fabric Samples

Bilsay Sümer

Department of Mechanical Engineering, Hacettepe University, Beytepe, 06800, Ankara, Turkey

Abstract

Tactile psychophysical tests were conducted on different surfaces to observe the regulating behavior of human beings. Subsequently, friction induced vibration on textile fabrics was investigated using an artificial finger experimental setup capable of maintaining a constant preload on the substrate. To obtain the constant preload, three different types of controllers were implemented and compared. Kinematic experiments were conducted for repetitive fabric textures with different normal loads and velocities to find the friction force maps. The constant preloading experiments revealed the dominant frequency of the textile pattern and were capable of filtering the other frequencies. Moreover, an artificial finger was able to detect a spatial texture pattern with an error of less than 4.4%, as compared to the values derived from image processing.

Keywords: Friction, Force Control, Textile, Touch

1. Introduction

Explicit object properties, such as the shape and physical dimensions, may be recognized by human beings only through visual sensation. However, the detailed properties of objects, such as the compliance, texture roughness, and temperature can only be identified by touch. Indeed, the dexterous and stable grasp or exploration of any object by human beings requires a collaborative effort of the touch and vision senses, and may even require additional sensing, such as auditory sensations [1–5].Therefore, recently, sophisticated sensory systems, such as tactile, vision, inertial, and auditory feedback systems, are being included in the development of humanoid robots [6–9].

Different parts of the human skin are proofed to have diverse sensitivity. The most sensitive parts of the human body are the fingers, whose outer layer is called epidermis, which serves as a protecting layer for the inner dermis layer, and comprises the papillary ridge. Recently, the papillary ridge, which contains the curly fingerprint pattern period, was shown to have a possible effect on the perceptual ability of textures [10]. It has been shown that the spatial period of the texture induces vibrations corresponding to the fingerprint spatial period, and this fact may amplify the transmitted stress signal to the inner layer. The receptors are located inside the dermis, which is a viscoelastic medium owing to the extracellular matrix (ECM). Different receptors, such as the mechanoreceptors, thermoceptors, and nociceptors, are available in the human fingers, and are usually classified according to their task specialization during the cutaneous process [11, 12]. Among them, the mechanoreceptors are responsible for mechanical perception, whereby, a complex mechanotransduction mechanism employs the multiple layers of the human finger [13].

When a human finger touches or moves on any surface, the stimulus due to the contact causes a local deformation at the interface, which leads to the distortion of a group of receptors located in the dermis layer [14–20]. The receptors with different characteristics and location of the touching area acquire dynamic stress, which amplifies and transmits the frequency and amplitude information and other data, such as temperature, to the brain for further processing. Various different receptor types exhibit different characteristics as a response to stimuli, typically in the range of 0.4-1000 Hz. The four main mechanoreceptors are the Merkel cells, and the Meissner, Ruffini, and Pacinian corpuscles [21]. Briefly, Merkel and Meissner receptors are located near the epidermis and are responsible for the detection of local stress, whereas, the Ruffini and Pacinian receptors are located in the deeper parts of the dermis and account for comprehensive stress envelopes. A further distinction of mechanoreceptors can be made with regard to their response speed to external stimuli [22, 23]. The Merkel Cells and Ruffini corpuscles, which are widely known as the slow adapting (SA) cells, have slow response characteristics with an approximate frequency bandwidth of 0.4-100 Hz. The Meissner receptors are faster than the slow adapting cells and have an estimated bandwidth of 10-200 Hz, while the fastest response is attained by the Pacinian corpuscles, with an approximate frequency bandwidth of 0.4-100 Hz. It has been shown that the slow adapting mechanoreceptors are responsible for quasistatic touch, such as texture perception and grasping. On the contrary, the fast adapting mechanoreceptors are responsible for dynamic touch operations such as grip control and using an apparatus [13, 19, 24]. Indeed, the touching process is a self-regulating one, and is performed until the human is fully satisfied with decision making by touching the surface [25, 26]. As an example, the human finger tracks the surface texture by changing the position in the vertical direction to apply a constant preload value to the examined surface.

Research activity related to the psychophysical haptic field and skin friction has focused on measuring normal and friction