

Skin-Integrated Devices and Systems for Haptic Interactions

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Abstract. The present situation for haptic feedback is in a urgently booming tendency concerning the issues that influence the user in every move. Therefore, the skin-attachable haptic sensor is now in higher and more demanding requirements where there are many aspects of the problem that people frequently encounter. First, the texture cannot be harsh, leading to the dilemma where it cannot fit in communal areas, create a twist, cause an uncomfortable experience and even trigger allergic reactions. Next, color and size are essential for aesthetic demands and a person's well-being. Finally, and most importantly, the proper mechanism of the detection system and the issue of energy supply. This paper mainly focuses on soft skin-haptic actuators for vibrotactile and kinesthetic feedback and soft skin-haptic actuators for high resolution and multimodality, respectively. The whole paper gives a thorough understanding of several sensors targeting different factors. To gain a clearer picture of the present statement, factors provided from different aspects could be of great assistance in tracing various symptoms and clinical treatment, witnessing a bright future.

Keywords: Haptic Actuator, Interface, Kinesthetic Feedback, Resolution.

1. Introduction

Skin-integrated electronics are California wearables for physiological signal detection and healthcare monitoring that are implanted on the skin. Thanks to their thin, soft, and outstanding mechanical behavior, they may be laminated on human skin without irritating it and in a conformal manner for real-time multipurpose intelligent sensing (stretching, bending, and twisting). The current state of skin-integrated electronics that can perform intelligent functions such as physiological sensing, sensory perception, and virtual and augmented reality (VR/AR) is summarized in this paper. These electronics can be used for a range of purposes, also as detecting bodily motions, tracking chemical and physical health signals, and creating fake visual, auditory, and tactile elements. These skin-integrated systems concentrate on the materials and structural designs that could allow the creation of the e-ears, e-eyes, and e-skin of the next generation of multidisciplinary research in the realms of materials science, electrical engineering, mechanics, and biomedical engineering will set the stage for improvement in this course of study [1].

The current technology is haptics, which goes beyond the use of visual and auditory cues to improve the quality of the experience of virtual or augmented reality. Platforms are currently being studied that provide spatiotemporal sensory modalities for the skin not only through the fingertips but also via any regions of the body, using thin skin-like technology that provides a negligible physical load on the user. This essay seeks to discuss the biological basis of this kind of skin interface as well as a wide range of applications in haptics, like electrotactile and vibrotactile devices that support touch perception in form factors with potential for the skin-integrated interface, in the context of this challenging goal. In the content, there is a focus on how to integrate these stimulators into programmable arrays. With a focus on scaleable materials and designs that could allow expansive soft skin interfaces, the content includes a study of the possibilities for fusing various stimulators into programmable arrays. The final chapter also describes the main multidisciplinary issues and important areas for further materials science and engineering exploration, and the consequences of successful research in this field [2].

2. Skin-integrated haptic interactions

2.1. Soft Skin-Haptic Actuators for Vibrotactile and Kinesthetic Feedback

Electrotactile neural stimulation and a range of haptic feedback actuators, such as those found on electric and magnetic, and piezoelectric properties, are expected to correctly deploy haptic interfaces for mimicking touch engagements in Virtual - reality. The most cutting-edge cases indicate how these elements may well be implemented into tiny, flexible substrates with material removal power sources and broadband control methods in transdermal skin interfaces with sustained tactile response functionalities [3].

Another team in Korea reported a soft, flexible wireless haptic interface capable of delivering spatiotemporal patterns of direct contact throughout the skin, potentially with comprehensive insurance, as well as the ability to reveal vibrotactile correlations throughout all reasonably great areas on the surface in individual units or via a wireless data coordinated compendium of them. Its density of 0.73 transmitters per square inch in the Vibro-haptic actuator panels displayed in these devices is larger than the two-point differentiation criterion for musculoskeletal perception upon that epidermis. Mechanoreceptors in the epidermis may acquire a wide variety of colorful sensations and availability of information by time-dependent sequences and amplitudes of stimulation controlled in real-time with hardly any latency by pressure-sensitive touchscreen devices on electronic objects. The researchers then investigated how this technology may also be used to deliver navigation system instructions, interpret musical patterns into haptic signals, and generate sensorimotor replacement inputs for the robotic prosthesis [4].

Xing Yu's results demonstrated a Bluetooth, battery-free platform of power equipment and haptic interfaces capable of attaching vinyl to the skin's curved surfaces and transmitting data via spatial and temporal programmable patterns of localized piezoelectric crystals.

The resulting innovation opens up a wide range of possibilities for use wherever skin exists to serve as a digital format computer-controlled interaction and sensorimotor conduit to the stomach, as evidenced by applications in social networking sites and application was designed artificial limbs control and responses, entertainment, and amusement. [5].

The Seongcheol team created a tactile stimulation interface for wearable devices using soft actuators. The soft actuator is constructed via a hierarchical aggregation of tiny electro-active polymer sheets. For the soft haptic actuator, silver nanowires form a multi-layered device that blends a tiny

Dielectric elastomer is coated by such a flexible, responsive electrode. When the user's fingertip comes into contact with the soft actuator's large protrusive deformation caused by electric potential, they can feel the tactile output. The electrically induced convex protrusive deformation of the multi-layered activator, which may be actively adjusted for diverse tactile inputs, is expected to be created. The multi-layered dielectric elastomer actuator is embedded onto curvilinear surfaces, like a fingertip on a rubber glove or a forearm band, to make the wearable interface. When the soft actuator is electrically triggered, it creates a sizeable lateral deformation, resulting in a haptic output that such a user may feel when in touch with the skin. The vertical displacement extension is 650 mm, and the maximum output force is 255 mm. soft actuators are found in the front section of a forearm band and the fingertip area of a glove. In two different types of experiments, they used 15 people. At 1 Hz and 191 Hz, the vibrotactile intensity and perceived actuator protrusion magnitudes were measured, respectively.

Using the dynamic input signal, the actuator maintains an amplitude deviation of the output force of less than 1% throughout 1,000,000 cycling operations. The suggested soft actuator delivers five levels of stimulation to the forearm and four distinct stimuli to the fingertip. The soft tactile actuator demonstrates its ability to provide scalable tactile stimuli to the user when integrated into a smooth and curvilinear wearable interface. According to the results of the user testing, subjects sense adjustments in protrusion level at the palm pad as well as changes in vibration strength via the suggested soft actuator-based haptic interface [6].

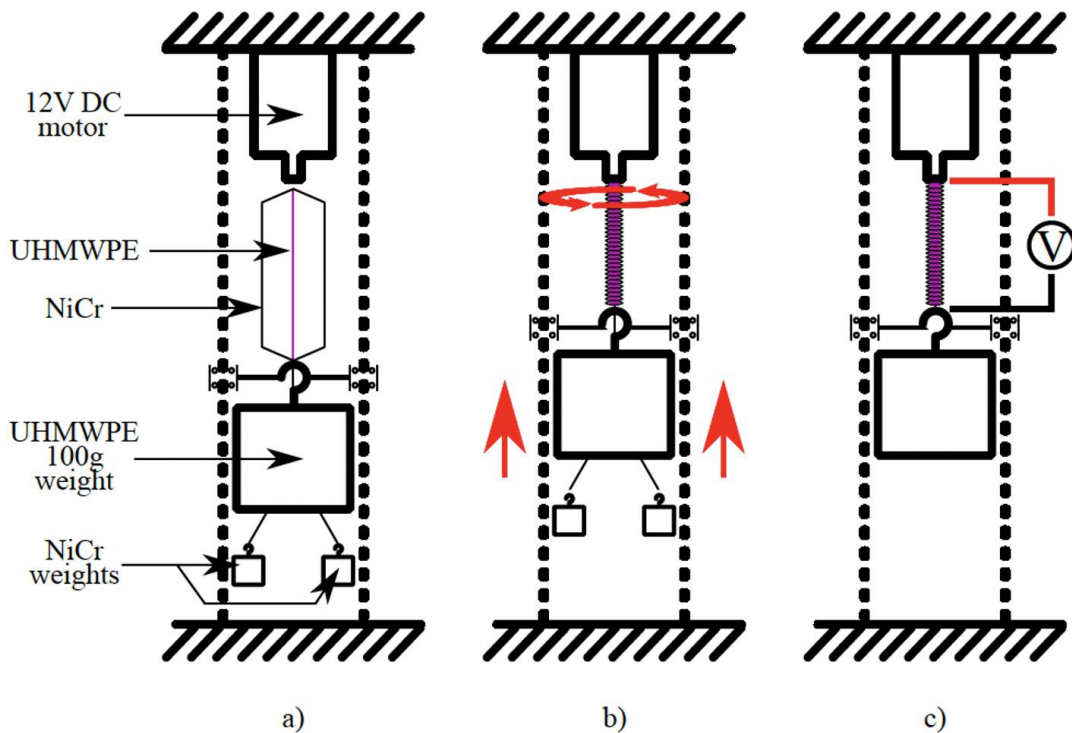


Figure 1. Schematic of the TCP actuator manufacturing process. (a) Initial fibers setup, (b) twisting and coiling of the fibers, (c) annealing and thermal setting through Joule effect heating [7].

This type of actuator uses ultra-high molecular weight polyethylene fibers to produce lateral skin stretch sensations. Due to high compliance or adhesion, silicone elastomers have been utilized in haptic applications and wearable sensors. Correspondingly, twisted and coiled polymer (TCP) actuators have been shown to have considerable stroke lengths, straightforward mechanisms, and high power-to-weight ratios. Because it is sensitive to tiny movements, lateral skin stretch is used in intuitive postural control feedback applications. A Chinese team harnessed these qualities to create a wearable, practical haptic working model. The prototype's effectiveness was tested with 14 healthy male subjects using an optical monitoring program and a force measurement test environment, and it was compared to mechanoreceptors' mechanical input. The results demonstrate that, notwithstanding the lengthier task filming schedule, participant median reaction rates were akin to those of a haptic feedback-controlled system [7].

Overall, teams from various places generally adopt the soft material that attaches the skin well and transforms the tactile and vibrative signal into an electric signal to be processed by a computer or other silicon-based chips. Therefore, it shows a good-looking prospect for this actuator to be applied to virtual reality or amusement industries.

2.2. Soft Skin-Haptic Actuators for High Resolution and Multimodality

The human body's tactile receptors have high bandwidth, excellent spatial resolution, and the ability to detect both normal and shear forces. Additionally, their dynamic range of displacements is broad, ranging from micrometers to millimeters.

The study demonstrated that the submillimeter-thick flexible hydraulic amplified electrostatic actuator (HAXEL) is capable of both out-of-plane and in-plane motion, delivering shear and regular forces to the user's fingertips or arm for dense and adaptable skin tactile input.

Compared to Peano-HASEL, HAXELs can reach more out-of-plane strain due to its use of polymers with such high breakdown voltage levels permittivity. This is possible while still maintaining a high energy density. Arrays of HAXELs are showing promise for lightweight, flexible, and dense haptic interfaces for VR, including patches for any part of the body as well as gloves, sleeves, and bracelets., thanks to their incredibly thin form factor and compliance.

Several crucial properties for haptic devices, microfluidics, or soft robotics are added by a stretchy central membrane. The stretchable layer is supported by the flexible membranes, which during the actuation, do not experience in-plane strain. As a result, HAXEL is especially well suited for building large actuator arrays. The flexible, stretchy HAXEL membrane can adapt to its surface and offers finger-skin-like compliance.

The effects of actuator factors (geometry, material, initial filling pressure) on force-displacement characteristics were investigated using a simulation model developed by COMSOL, a finite element modeling program, thus playing the role of design tools. The outer border of the cavity, where there is the smallest spacing between the electrodes, is where zipping starts when a voltage is applied. Smaller inner diameters produce more significant displacements for fixed outer diameters, while all around, displacement is maximized at a 20-mbar starting pressure.

The HAXEL arrays' flexibility allows for mounting on the body and the creation of rich wearable virtual reality objects, such as gloves. They might be made in a variety of sizes and shapes to fit each individual body part, creating a full-body haptic suit that is electrically powered and light.

According to haptic user studies, the shear and typical stresses generated by these mm-scale actuators were easily felt by human test subjects. Therefore, HAXEL actuators show promise for basic manipulation tasks as well as sophisticated haptic feedback, such as sliding friction and texture rendering [8].

Haptic devices are generally better at replicating the bulk characteristics of materials than their surface features. The ability of a haptic glove to imitate three different kinds of near-surface characteristics, such as hardness, temperature, and roughness, is discussed in this paper. The sensations of hardness and temperature are made possible using thermoelectric devices and easily accessible commercial vibrotactile motors. On the other hand, a conductive, bioinspired-conjugated elastomer duplicates the roughness sensation through an electrotactile signal.

Although haptic effects are common in consumer electronics (such as game controllers, cellphones, and smartwatches), their ability to produce different kinds of feelings is constrained. In general, they perform an excellent job of signaling events (such as phone calls, on-screen action, and text messages). Still, they generally do a worse job of simulating the tactile characteristics of materials found in the real world.

They chose vibrotactile stimulation, which involves inserting commercial vibrotactile motors into the haptic glove's fingertips to recreate the feeling of hardness. In psychophysical investigations, vibrations of lower amplitude were regarded as softer than those of higher amplitude when they made touch with the surface of a virtual item. The participant experienced either heating or cooling depending on the size and polarity of the voltage source. The surface temperatures of the virtual objects were produced using thermoelectric devices. They employed the electrotactile effect to simulate the surface texture.

They evaluated the effectiveness of touch gloves in a virtual reality environment. In the presence of signals from both vibratory tactile devices (signal hardness) and thermoelectric devices (temperature), they wondered whether electrotactile devices could be used to reproduce textures (rough and smooth).

In recognizing the characteristics of the virtual panels, trained participants fared noticeably better than untrained participants (98.3% total accuracy vs. 85% correct) based on a logistic mixed-effect regression model. The results demonstrate that participant ability to identify between emotions differs depending on the sort of stimulus employed. In general, they reached the conclusion that the haptic glove provided sensations that knowledgeable users could accurately distinguish from another.

The heightened sense of reality that can be produced is one of several ongoing difficulties. Nevertheless, they think that for haptic interfaces to be completely realistic, new materials may need to be created that may produce sensations incompatible with actuators already available. But they emphasize the significance of molecular structure-level chemistry and material design [9].

3. Discussion

We commence by presenting a receptor discovered by a Korean team. It may produce vibrotactile patterns over huge areas of the skin and provide spatiotemporal tactile patterns over the entire body through a wirelessly coordinated combination, possibly covering the full body. Except for the hands and face, this sensor's advantage is that it incorporates a range of vibrotactile actuators at a density of 0.73 actuators per square centimeter, surpassing skin-mechanical feeling in almost all body regions. the discrimination limit of 2 points. A range of vibrant sensations and information content can be rapidly transmitted to skin-surface mechanoreceptors through transient patterns and actuation amplitudes controlled in real-time by the pressure-sensitive touchscreen of the smart device. The fact that this feeling is costly and that the research is complex is a downside.

the discrimination cutoff of two points. A variety of vivid sensations and information content can be conveyed to mechanoreceptors in the skin with little buffering using transient patterns and actuation amplitudes controlled in real-time by the pressure-sensitive touchscreen of the smart device. Of course, it is a disadvantage that this sensation is expensive and that the research is challenging. Multilayer actuators with electrically generated convex deformations can be dynamically tuned for various tactile stimuli. Wearable interfaces are created by embedding multilayer dielectric elastomer actuators into curved surfaces like rubber gloves or the points of forearm bands. The user can sense the tactile output of the large vertical deformations of the soft actuators brought on by power activation through skin contact. The benefit of using this kind of sensor is that it offers people to touch and experience that is more useful and lifelike. They are also very picky about the materials they employ, designing an interface that mimics the gradients of the human body without interfering with internal circuitry. The weakness of this sort of interface is that it takes a lot of care that was easy to damage. The third shows a wireless, battery-free electronic system and tactile interface platform developed by Xing Yu's team. It may convey the data via spatiotemporal programmable patterns of localized mechanical vibrations and be sensitively laminated to the curved surface of the skin. This sensor's additional benefit is that it applies this technology to provide electronically programmable channels of communication and body sensory input to the skin, going to open up a whole range of usage opportunities, as demonstrated by applications in social media and personal engagement, prosthetic control and feedback, gaming and entertainment [10].

4. Conclusions

The work demonstrates thorough comprehension of various tactile feedback devices for multiple factors. Usually, soft materials that cling well to the skin are used by many teams to transform touch and vibration inputs into electrical signals that a computer or other silicon chip can process. Additionally, certain devices make use of the benefits of stretchable interaction films, dielectric materials, and non-stretchable electrodes. They can move out-of-plane and in-plane, apply shear and normal force to the user's fingertips, hands, or arms, and achieve dense and flexible skin tactile feedback using elastomers for displacement. The primary applications for this kind of equipment are entertainment, healthcare, and so forth.

Additionally, it aids in the clinical management of patients and tracking symptoms. But the paper also reveals some significant challenges, including the high cost and the increase in the sense of reality that can be generated. The development of tactile devices that enhance realism will go hand in hand with improvements in manufacturing technology, especially in increasing the density of small drives on flexible and resilient substrates.

Despite these difficulties, developing new materials that may give a feeling that cannot be produced using off-the-shelf actuators may be necessary for the complete realism of the haptic interface. A larger variety of tactile sensations may be offered than is now the case by molecular engineering materials with real-time changes in surface energy, phase, oxidation state, thermal conductivity, and conductivity. Additionally, materials that permit small-scale controlled deformation

will speed up oil field finding compared to conventional pneumatic techniques. We also emphasize the importance of chemistry at the molecular structural level and material design.

Currently, relevant research has yet to find the best material for haptic feedback devices. Still, the actuator's sense of reality, soft touch, and accuracy have reached a high level. The medical applications of such devices are promising.

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