Haptics and Electromyogram (EMG): Recent Advancements and Future Aspects for Enriched Haptic Experience

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Abstract

Haptic technology has enabled rapid advancements in human-computer interactions and has opened up a wider spectrum of applications such as gaming, interactive computing, robotics, medical equipment advancements and many more. The study of haptic devices is an emerging area of interest among researchers due to its close relation to the very widely explored domain of robotics and artificial intelligence. The various types of haptic feedback- tactile, kinesthetic, force feedbacks, have been utilized in different applications. The electromyogram (EMG) signal depicting the electrical activity of muscles has been utilized in haptic systems in the form of feedback, and there have been various developments in haptic devices as well as EMG signal processing in recent years. This study presents a brief review of the basic concepts of haptics, EMG, the recent advancements in these fields, and the present state of research applying the combination of haptics and EMG together to obtain enhanced outputs that can be utilized across various applications.

Keywords: *- Haptics, Tactile actuation, Kinesthetics, Force feedback, Electromyogram (EMG).*

INTRODUCTION

The term ’haptics’ encompasses all forms of non-verbal communication, including the tactile form of conveying in- formation. The exploration of this technology comes with a vast horizon of applications that have enormous potential for research in the imminent future. The sense of touch, particularly, has come up as an additional form of sensing and feedback, after the two most used modes of visual and audio outputs. This was initially brought into existence in order to improve user experience, especially in gaming, with more rich and realistic simulations and interactive experience. Additionally, the sense of touch allows human beings to perform various exploring and manipulating tasks in reality, while this needs to be simulated in case of a virtual scenario for a variety of applications such as medical applications of robotics where minute operations need to be performed with sharply designed machinery while providing real feedback to the human operator at a remote location while maintaining the high level of precision at the site. The simulation of touch sensation is very crucial for such scenarios. The various characteristics of matter that are artificially simulated to form the tactile feedback to be perceived by humans are state, stiffness, shape, roughness and texture, with the addition of force and torque feedback which constitute the kinesthetic senses which are perceived by muscles, joints and tendons. All these components together form a complete simulated haptic experience to facilitate virtual reality. Developments started with the simple simulation of virtual objects have undergone a lot of advancements in the past decade. Interestingly, the field of medical prosthetics, or bionic limbs aided by haptics, has undergone quite a lot of research and with the help of Electromyography (EMG) or electrical activity monitoring of skeletal muscles as feedback to enhance the system performances. This feedback can be extended in its applications to a wider horizon of applications allowing refinement of the perceived signal and the overall experience. The following sections provide a detailed overview of the basic concepts of haptics, the EMG signals and the various advancements in the fields in recent years.

HAPTIC TECHNOLOGY DEVICES

The haptic devices can be broadly classified into three main categories: graspable, wearable & touchable, as depicted in fig. 1 [1]. As visible in the image, the devices with graspable interface provides hand-held equipment to be felt and exerted pressure on. The wearable haptic devices, as the name suggests, provides a tactile device worn on the wrist or any other suitable body part to transmit the tactile sensation directly to the skin. These sensations may include skin deforming forces, stretches or vibrating cues while leaving the user free to move and keep performing their normal activities. On the other hand, the touchable interface provides a tactile surface with varying property such as stiffness, smoothness or texture, which the user can actively sense to differentiate the nature of the surface. These devices might as well be used in conjunction with kinesthetic or force feedback systems in order to provide an enhanced experience.

Fig. 1: Various types of haptic devices [1]

A. Tactile Actuators

The basic tactile actuation can be realized by different working principles, some of which are piezoelectric actuation, electroactive polymer actuation (EAP), electromagnetic actuation, shape memory alloy (SMA) based actuation, etc. These mechanisms can be described as below:

Piezoelectric Actuation: The piezoelectric-based actuation technique involves the converse piezoelectric effect and proves effective even with small amounts of strain which are enhanced by operating the structure at its resonant frequency. The piezoelectric material structure undergoes varying mechanical deformation when an oscillating voltage is applied to its electrodes. One of the configurations of this kind of actuation principle is the multilayer electrode-ceramic-electrode structure, as depicted in fig. 2 [2]. This configuration, called as 'bending motor' comprises a cantilever fixed at two ends and undergoing alternate shrinking and expansion in rhythm with the oscillating voltage applied, resulting in a vibration conveyed to the touch panel of the device.

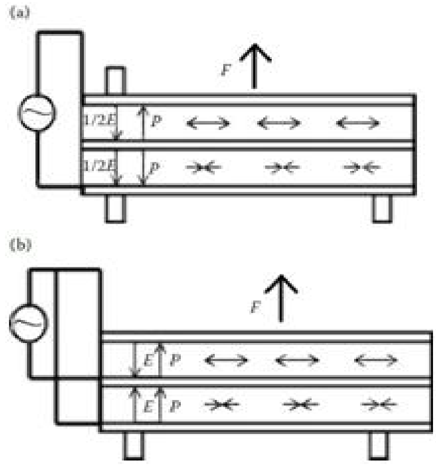

Fig. 2: Piezoelectric tactile actuation technique [2]

In fig. 2, it can be an observer that there are two types of connection: serial structure (a) and parallel structure (b). The achieved magnitude of force and displacement can be enhanced by reducing the thickness of the piezoelectric film and employing a multiple layer structure. Other than the basic structures, multilayer helical structures constructed by piezoceramic material may be used in various applications such as loudspeakers.

Electroactive Polymer Actuation (EAP): EAPs provide promising scope in the emerging tactile actuation techniques. These are basically soft materials that change in shape on applying an electric field. The flexibility and softness of these materials make them quite suitable for producing light and qualitative tactile information. IPMC and dielectric elastomers (DE) are the most frequently used EAPs. The IPMC has applications in soft tactile actuators. IPMC is not suitable for mobile applications since it exists in a gel form and has the requirement of the wet environment along with a large power requirement to provide actuation. The polymer material is placed in between two suitable electrodes where an electric field is applied to determine hydrated cation migration towards the cathode, whereas the anions remain within the polymer matrix. Being encircled by water molecules, migration of the cations causes water accumulation near the cathode resulting in hydrophilic expansion, while the internal stress within the matrix results in its bending in the direction of the anode. The actuation voltage requirement is very low (nearly 5V), but in case the value is more than the material electrolysis voltage, the material is prone to degradation. DEs, on the other hand, do not possess intrinsic electroactive characteristics, but on the application of a suitable voltage onto a thin elastomer layer placed between two suitable electrodes, their attraction causes a significant strain. Stress (Maxwell stress) acts on this material layer, resulting in lateral stretching and compression in the material thickness. This technique requires very large voltages (order of thousands of volts), resulting in higher device cost. Large displacements have often been achieved by employing stacking of layers to realize actuator arrays for high-density tactile display within a single substrate. An implementation of the DE based actuation principle is through hydrostatically coupled DE (HCDE), as depicted in fig. 3 [2] where a fluid with low compressibility is placed between an active and a passive portion of DE with load interfacing, acting as a mechanical displacement transmitter.

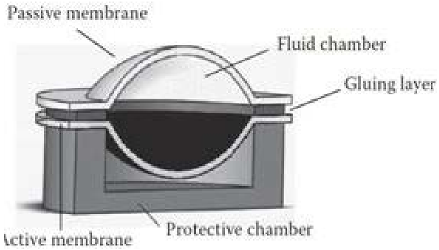

Fig. 3: Electroactive polymer (EAP) actuation technique [2]

With the application of an external voltage, there is an outward buckling of the active membrane causing the passive membrane to move inward because of a hydrostatic transmission. Here the active membrane does not come in contact with the skin of the user making the device electrically secure. Often, electrically insulating fluids may be used for further enhancement in safety. This actuator is observed operating at a frequency of 250 Hz at resonant condition, which allows the actuator well suited for applications, like tactile display. Often the rigidity in the case of tactile actuators may impose limitations on their applications, which make way for the growth and advancement of soft-tactile technology.

Electromagnetic Actuators: Apart from the piezoelectric and electrostatic polymer actuation techniques, magnetic actuation is an area of interest because of the high magnitude of magnetic force, high bandwidth, and non-contact mode of operation.

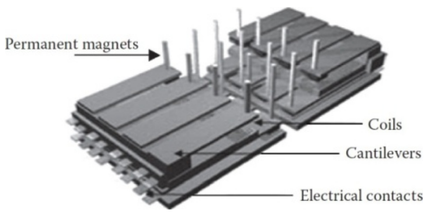

Fig. 4: Electromagnetic actuation technique for vibrotactile feedback [2]

Fig. 4 [2] depicts a vibrotactile actuator employing the electromagnetic actuation principle and based on a 4 × 4 polysilicon cantilever array having bonded integrated permanent magnets on its top. There are sixteen micro-coils positioned below the free ends of the cantilever beam. The coils produce a magnetic field directed parallel to the magnetization direction of the integrated permanent magnets in the device. This causes the generation of a force of attraction or repulsion determined by the input current direction. Another example of a similar device is a multilayer tactile display operating by electromagnetic actuation method. The layers constitute a micro coil PCB layer for the generation of the magnetic field with a flexible membranes layer on the top for direct contact with the users' fingers, with a permanent magnet made of NdFeB attached beneath each of the membranes. There is an intermediate layer for the purpose of separation. The operation frequency ranges up to 800 Hz, having a resonance frequency 270 Hz.

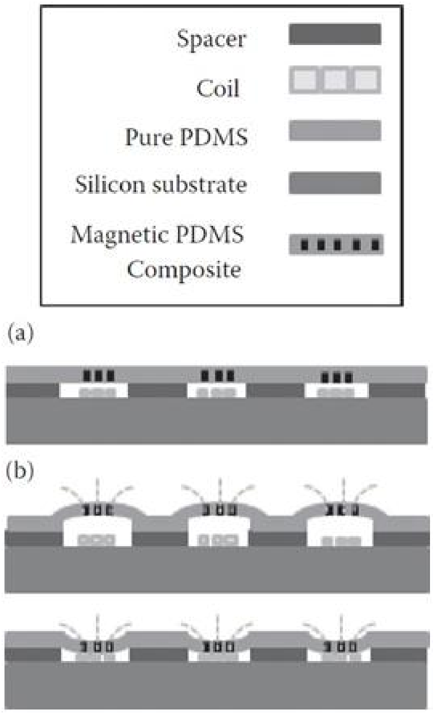

Fig. 5: Electromagnetic actuation with Magnetic PDMS membrane depicting (a) resting and (b) actuated modes of the device [2]

Presently, there are limitations to device miniaturization due to bulky nature of the magnets used in the fabricated structure, which may be overcome by employing a PDMS membrane consisting of magnetic nanoparticles (NPs), providing it with magnetic properties. This membrane undergoes deflection by an external magnetic field generated with the help of micro coils, allowing larger displacements. The device can be observed in fig. 5 [2]. The deflection varies according to the direction of current intensity and the NPs' magnetic nature. While the magnetic properties are affected, the mechanical properties such as flexibility and elasticity remain unchanged even with magnetic nanofillers being present in the PDMS membrane. The problems regarding the integration of magnetic material are overcome with the employing of magnetic NPs into polymers.

Shape Memory Alloy (SMA) Actuators: Compared to the other actuating techniques, the SMAs portray high displacement values. The working of SMA is based on the capability of deformation and restoration of materials with temperature, also known as the 'shape-memory' effect. Such materials are versatile, achieve high displacement with low volumes, and allow electrical as well as thermal actuation with significantly low noise. These materials also help in producing vibration effects by employing an oscillating input, often periodic signals. Various touch sensations may be produced by these systems aided by virtual sensations. Some major and critical applications of these devices are for helping the visually impaired by means of tactile stimulus to regenerate the information in the ambient environment with small, lightweight devices with good resolution and reliability. One such device is depicted in fig. 6 [2]. It comprises 8 by 8 tactile pins, where each taxel is a metallic pin with thermoelectric insulation, having a NiTi SMA wound in the form of a helical spring. The upper and lower halves portray independent actuation resulting from the grounding of the taxels at the centre. There are metallic joints to facilitate a reduction in friction, guidance of the pin motion, attachment of the SMA spring with the plate and connection of the pin with the electronic drive.

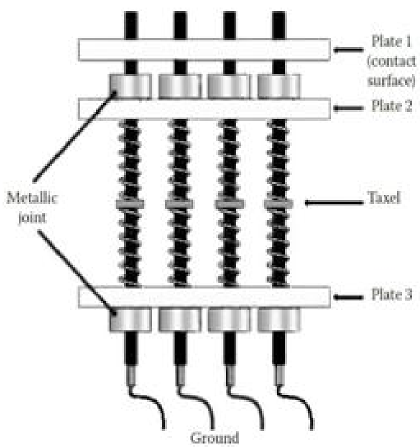

Fig. 6: Shape memory alloy (SMA) actuation technique [2]

B. Kinesthetics

The term 'kinesthesia' represents sensing of forces and motion, associated with the relation between forces and their resultant displacements, and 'kinesthetics' involves the study of motion and its perception by one's own body. This perception involves receptors such as muscle spindles and tendon organs, helping in sensing changes in muscular tension and stretching of muscles. A sensation of forces and movements can be simulated by creating stimulation to these receptors. The haptic devices working on the principle of kinesthetics have the ability to stimulate movement by applying forces to a joint area. Various kinesthetic based haptic devices have been developed ranging from one-DoF (Degree of freedom) to six- DoF implementations with substantial research performed to enhance realistic and stabile virtual scenarios rendered through special force-displacement dependent programs.

C. Other means of Haptic Actuation

Actuation by Skin deformation: Another method of actuation is by employing the skin deformation technique for feedback where a user's skin is stimulated by means of sheer force, imitating natural haptic interactions. Here, the finger being more sensitive, the shear forces make more impact on the finger surface as compared to normal forces. Apart from this, two degrees of freedom provide directional information through the shear forces. The acting device touches the skin surface, ensuring enough friction to cause deformation of the skin along with the shear. Such devices mainly focus on feedback perception by deformed skin surface. In more recent studies, this concept has been utilized together with the kinesthetic and forced feedback systems to generate a complete stimulus for actuation.

Tactile illusion in the form of vibration: Often, various vibrating actuators may produce a sense of illusion in terms of movements. The signal shape, time, and actuator spacing are significant factors in this. This sensation can be perceived in the form of a vibration travelling through the skin realized by the control of actuator array length and delay and have been implemented in navigation system applications. Such actuating illusions may also be generated by employing multiple vibrating actuators to allow the user to feel the sensation midway in between the different actuators, with the location determined by the amplitude ratio of the different actuators. The techniques of travelling vibration and multiple vibrating actuator effects have also been employed in combination to generate smooth tangible strokes termed as ”tactile brush” with the aid of a vibrotactile array. Another similar mechanism called ”cutaneous rabbit” employs short vibrating pulses one after another in separate locations on human skin, producing an illusion of sensation at the middle of the actuator positions. A very interesting advancement from the above-mentioned techniques is midair vibration systems, through which objects can be sensed in free space with no physical contact with the actuators. This is achieved with the aid of beams from an ultrasound transducer which generates an effect of pressure on the skin of the user, midair, which enables the sensation of different objects in the air. The intensity and phase are adjusted to generate pressure due to acoustic radiation. Various shapes, objects, midair screens, tangible icons can be realized through the above concepts.

D. Recent Developments

The basic concepts of some of the common haptic devices and haptic actuation techniques have been discussed in the above section. In this section, some of the most recent developments in the field of haptic feedback devices and materials shall be enumerated, which will clearly portray the current state of the art and the recent research going on in the domain of haptics.

In the recent work Poyraz and Tamer (2019) [3], haptic signals are generated utilizing individual vibration motors, with the aid of an Eccentric Rotatory Mass (ERM) and a Linear resonant actuator (LRA), enabling the user to distinguish between various signals on a surface. The different parameters such as amplitude, frequency and modulation are altered respectively to give rise to distinguishable messages through the sense of touch.

In another recent work, Adilkhanov et al. (2020) [4], a vibrotactile device named as ”VibeRo” has been proposed for the purpose of achieving haptic feedbacks of soft objects implemented with the help of haptic displacement illusion by means of force based vibrations synthesized from surfaces of contact. Another current research study, Singh et al. (2020) [5], presents a soft force sensor based on resistive mechanism and produced by 3D printing technique utilizing thermoplastic polyurethane (TPU). This work has been done to enhance bio-feedback systems and portrays how the various materials have undergone advancements and be easily available and affordable to be produced for testing and usage. Another recent work, Barreiros et al. (2020) [6], describes the manufacturing process of a composite elastomer membrane, which has a self-sensing capability, along with the descriptionof the process by which the device is integrated as well as the usage of deep learning in order to estimate state. Various other developments have been achieved in this area, with more and more low-cost solutions coming into play. At present, various materials are commercially available to facilitate research of the devices. Nowadays, 3D printers also have helped a lot in the production of the desired materials in their desired shapes and dimensions for customizable systems.

ELECTROMYOGRAM (EMG) AND HAPTICS

A. Basic concepts of Electromyography (EMG)

Electromyography (EMG) is a method involving the generation and processing of myoelectric signals, which represent the changes in the physiology of muscle-fibre membranes. It can also be described as the study of the activities of muscles by means of investigation of the electrical pulses generated during these activities. The Kinesiological EMG mainly monitors neuro-muscular activation of the muscles due to varying postures, motions, and medical training sessions. Apart from physiological and bio-mechanical research, kinesiological EMG has found applications in fields like applied research, physiotherapy and medical training, Orthopedic research, Functional Neurology and posture analysis. EMG signals have been significant in various health-related fields, such as detection of conditions such as Huntington’s disease or myopathies, which have aided in the early detection of heart and brain-related issues through regular monitoring.

The main muscle functioning and origins of the EMG signal are described in this section. A motor unit can be stated as the smallest functioning unit in neural control during the contraction phenomena of muscles. A motor neuron, with its cell body as well as its dendrites, axon, and associated muscular fibres- altogether constitute the motor unit. One very important element in muscle physiology is the ability of muscle fibres to be excited by means of neural stimuli. There is an ionic equilibrium in between the two areas- inner & outer, in a muscle cell which gives rise to a resting potential near the membrane of the muscle fiber, and a difference of potential is conserved by the aid of physiological processes causing a negative charge within the cell as compared to the exterior surface. An alpha motor horn cell is activated due to some generated reflex, which allows the excitation to be propagated through the motor nerve. The flow of sodium ions results in mild changes in the muscle diffusion characteristics, which results in the depolarization of the membrane, followed by an immediate reverse ion-exchange mechanism restoring the earlier state termed as a re-polarization mechanism. In case the sodium influx surpasses a certain level, the "action potential" suffers a drastic change from a negative range towards a positive range.

A monopolar electrical burst is instantly restored as a result of the re-polarizing mechanism succeeded by a membrane hyper- polarizing period. The action potential propagates through muscle fibres after being initiated at the motor end-plates, towards all directions as well as within muscle fibres by means of a tubular system. This, in turn, allows calcium ions to be released within the cell space, eventually resulting in the muscle cell contracting elements being shortened. The EMG signal is basically originated through the action potentials generated as a result of depolarizing and re-polarizing process at the muscle fibre membranes.

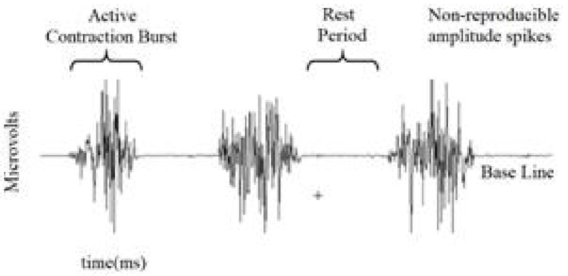

Fig. 7: Phases of three contractions of a muscle in the unprocessed EMG signal [7]

An unprocessed EMG signal is depicted in fig. 7, where it is recorded at the surface for a bicep muscle contracting three times. The applications of EMG signal analysis and the developments in its form factor can be noted in one of the recent works in the field, Bi et al.(2020) [8], where a prototype wearable system is described, which facilitates rehabilitation through multiple gestures, with the help of surface electromyography generating an electrical stimulation through the forearm. This prototype has been proposed for the reconstruction of multiple gestures for patients suffering from limb paralysis and the detection of such sites on the limb of a healthy person. The proposed arm wearable with an eight-channel sEMG detection system and its positions are depicted in fig. 8 [8].

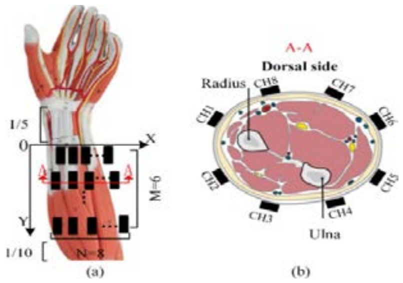

Fig. 8: (a) An EMG sensor armband prototype and (b) Cross sectional view of placed sensors [8]

B. EMG in haptics

The role of haptic feedback and EMG signal monitoring in medical applications has been studied extensively over the years to facilitate the better performance of prosthetics, as well as in rehabilitation exercises. A few of the many works are discussed in this section.

In earlier work, Cikajlo et al. (2013) [9], a virtual reality (VR) environment having a haptic floor has been described to target the ones suffering from Brain Stem Stroke, which affects the area of the brain coordinating movements. The people who survive such conditions face difficulties such as foot drop, spasticity, balance problem, weakness due to the scrambling of brain signals. This work describes that by employing VR along with the Haptic floor, a virtual environment can be created to facilitate balance training. The process of telerehabilitation balance training provides the scope to help treat the patients after being discharged from the hospital from the comfort of their home.

The recent work by Bertucco et al. (2019) [10] addresses the issue of Children's Dystonia which is related to involuntary muscle contraction, which in turn results in unexpected posture and movement-related abnormalities, including unwanted rapid movement, twisting, etc. Vibro-tactile EMG based biofeedback is popularly used in neurorehabilitation and physical therapy, as it facilitates the awareness for controlled muscle activity.

In the mentioned work, a portable vibrotactile EMG-biofeedback device alerts the person wearing the device of their muscle activity by smoothly altering the speed of the vibrational motor, i.e. augmented sensory data results in improving motor function. EMG-based biofeedback can have therapeutic use by enabling children to explore different solutions and thus, helping in acquiring new motor skills.

Another recent work, Pradeep et al. (2020) [11], talks about bionic hands, which are made affordable to common people owing to haptic sensors. Amputation of the limb can be due to injuries, osteomyelitis, peripheral vascular disease, diabetes, and many other medical conditions resulting in amputee hinging on others for their daily routine. Bionic hands can accrue an accuracy of up to 95%. The working principle of this device is: it collects biosignal like electroneurogram, electroencephalogram, surface electroencephalogram, etc., which are further processed to identify the action the amputee desires to perform. The haptic sensor makes the bionic hands lighter, like a normal hand.

ENHANCEMENT OF HAPTIC OUTPUT WITH THE HELP OF EMG FEEDBACK

In this section, the outline of a proposed system is presented in the form of a block diagram, as depicted in fig. 9. Data collection and testing need to be performed in order to validate the performance enhancement. The entire process of haptic simulation focuses on the successful regeneration of complex tangible objects in the virtual environment in a highly refined manner.

The sole objective is to enhance the perception of the simulated objects by the human skin. While the concepts of haptics and EMG have been studied together for mainly medical applications such as prosthetics and rehabilitation, the concepts can be further extended to a wider spectrum of applications where the EMG signals generated by the human muscles can be processed and with the help of extracted features, the sensed or ”held” object can be attempted to be identified, depicting a reverse mechanism. Although the validity of such a concept needs extensive data analysis to be proven, an outline of the idea is shown in fig. 9.

The flow of the system is as follows: The ”Virtual Object Parameters” block defines the set of data and characteristics which qualitatively define the complex virtual object. This data will act as a source to correctly simulate the given object. Such data specification may include shape, dimensions, weight, density, and type of material, rigidity, surface texture, friction coefficient, and many more. The”Data Processing Module” performs the dataset reduction and conversion of the object parameters into quantifiable values, which is then fed to the”Feature Extraction” module. These extracted features serve as input to the ”Haptic Rendering Algorithm,” which helps in converting the features into the electrical impulses to be supplied to the tactile as well as kinesthetic actuation modules to generate the correct haptic output. Together, this constitutes the”simulation module”.

The haptic output is then perceived by the human skin by means of touching or holding the object, which generates electrical impulses in the human muscles. This gives rise to changes in EMG signals which can further be processed and passed through a learning process (through the training module involving the ground truth). Hence a learning algorithm can be devised to correlate the two signals and can be used as a refining mechanism to enhance the virtual regeneration of the object. The ground truth here consists of the real object description, which is used to enable the training phase of the feedback module.

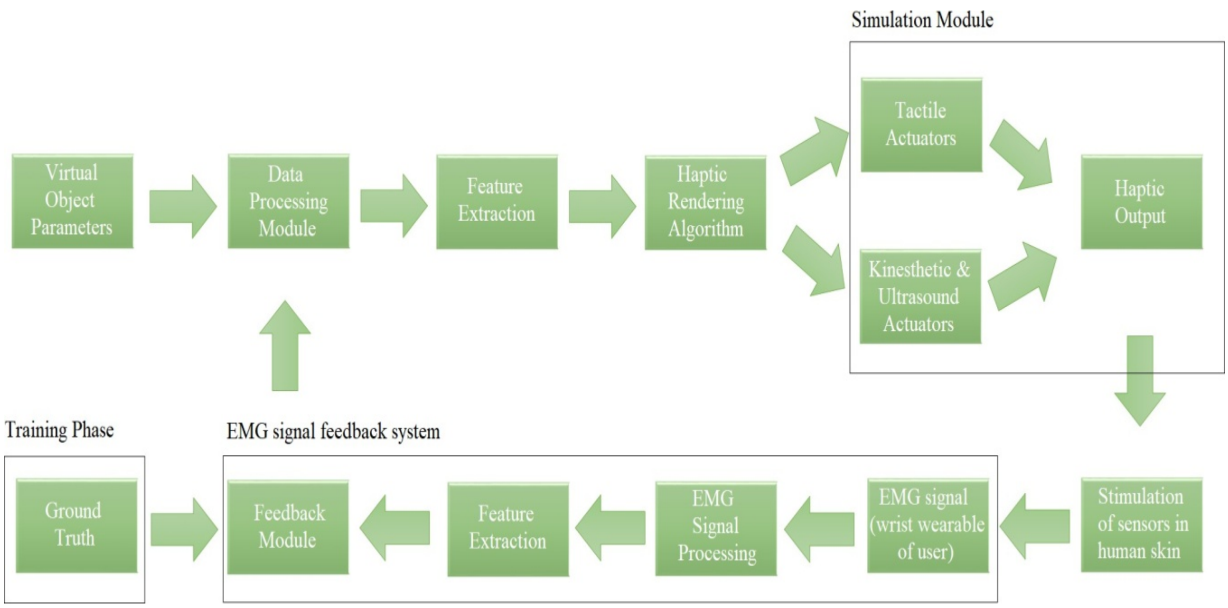

Fig. 9: Block Diagram of the EMG Feedback-based Haptic simulation system

CONCLUSION

As discussed in this study, haptic devices and materials have undergone a lot of research and advancements since its first introduction. Beginning with primarily a tool to enrich gaming experience, its applications have extended from virtual reality to robotics, AI, medical tools as well as interactive computing. The area of haptics primarily encompasses tactile can also be used to enhance its performance. This field has been explored well in the field of prosthetics and assistance, and it may be further studied for the purpose of research in various other applications. With artificial intelligence depicting a promising future, extensive research in the area of haptics is one of its crucial building blocks in the years to come. An outline of such a haptic simulation system, employing feedback through human-generated EMG signals and learning algorithms, has been proposed in this work and allows the scope for further research and extensive data analysis methods for testing and implementing this concept.

REFERENCES

1. H. Culbertson, S. B. Schorr, and A. M. Okamura1, “Haptics: The present and future of artificial touch sensations,” 2018.
2. V. Choudhary and K. Iniewski, Eds., MEMS FUNDAMENTAL TECH- NOLOGY AND APPLICATIONS. CRC Press, 2013.
3. G. G. Poyraz and O. Tamer, “Different haptic senses with multiple vibration motors,” in 2019 11th International Conference on Electrical and Electronics Engineering (ELECO), 2019, pp. 870–874.
4. A. Adilkhanov, A. Yelenov, R. S. Reddy, A. Terekhov, and Z. Kap- passov, “Vibero: Vibrotactile stiffness perception interface for virtual reality,” IEEE Robotics and Automation Letters, vol. 5, no. 2, pp. 2785–2792, 2020.
5. D. Singh, C. Tawk, R. Mutlu, E. Sariyildiz, V. Sencadas, and G. Alici, “A 3d printed soft force sensor for soft haptics,” in 2020 3rd IEEE International Conference on Soft Robotics (RoboSoft), 2020, pp. 458– 463.
6. J. Barreiros, I. Karakurt, P. Agarwal, T. Agcayazi, S. Reese, K. Healy, and Y. Menguc, “Self-sensing elastomeric membrane for haptic bubble arrray.” in 2020 3rd IEEE International Conference on Soft Robotics (RoboSoft), 2020, pp. 229–236.
7. P. Konrad, The ABC of EMG: A Practical Introduction to Kinesiological Electromyography, 2005.
8. Z. Bi and et al., “Wearable emg bridge- a multiple-gesture reconstruction system using electrical stimulation controlled by the volitional surface electromyogram of a healthy forearm,” 2020.
9. Cikajlo, A. Krpi cˇ, and M. Gorisˇek-Humar, “Changes in emg latencies during balance therapy using enhanced virtual reality with haptic floor,” in 2013 35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), 2013, pp. 4129–4132.
10. M. Bertucco, F. Lunardini, M. Nardon, C. Casellato, A. Pedrocchi, and T. D. Sanger, “Vibro-tactile emg-based biofeedback induces changes of muscle activity patterns in childhood dystonia,” in 2019 9th International IEEE/EMBS Conference on Neural Engineering (NER), 2019, pp. 53– 56.
11. R. Pradeep, L. S. Praveen, and P. Shankpal, “Implementation of multiple dof bionic hand for emg controlled schemes,” in 2020 2nd International Conference on Innovative Mechanisms for Industry Applications (ICIMIA), 2020, pp. 36–40.