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Haptic Technology in Networked Digital Applications: A Literature Review

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Abstract – Haptic-enhanced network applications provide a breakthrough merger of haptic technology with digital environments, allowing for immersive and responsive interactions. In contrast to traditional interfaces that rely primarily on visual and auditory feedback, these applications add tactile sensations, boosting user engagement in domains such as telemedicine, Virtual Reality (VR), Augmented Reality (AR), gaming, and remote collaboration. This study adopts a systematic literature review methodology to identify, filter, and analyse relevant academic sources published between 1998 to 2024, to examine accomplishments, challenges, and future directions of haptic technology in network applications. The study investigates actuator technology, tiny haptic devices, and adaptive algorithms that refine tactile feedback using a thorough review of literature and technical reports. Haptic-assisted telemedicine allows surgeons to do remote treatments with greater precision, and virtual training simulations mimic real-world interactions. Despite its benefits, integrating haptic technology presents problems such as high implementation costs, latency issues, and cross-platform interoperability limits. The need for high bandwidth and real-time data processing complicates wider adoption. As the global haptic technology industry grows, collaboration between engineering, neuroscience, and human-computer interface fields is expected to lead to more innovation. The future of haptic-enhanced network applications relies on improving real-time feedback accuracy, reducing hardware limitations, and making technology more accessible to encourage broader user adoption. This review aims to explore how haptic technology can change digital interactions, making virtual experiences more tangible, intuitive, and effective.

Keywords— *Haptic Display, Cognition, Tactile Devices, Force Feedback, Sensors.*

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1. INTRODUCTION

In an era where technology continuously shapes our digital landscape, the transition from static interfaces to immersive and interactive experiences in network applications has been nothing short of remarkable. The need for more responsive, engaging, and intuitive applications has grown as the digital landscape changes further. In the past, users were largely engaged, and information was conveyed by visual and audio signals in network applications. These modalities were moderately interactive, but they lacked the realism and depth required to replicate in-person

encounters. But recently, there has been a notable shift and the addition of Augmented Reality (AR) and haptic interaction to conventional audio-visual content improves the immersive and interactivity of viewers with rich content services [1]. As the benefits of haptic technology continue to gain attention, the global haptic technology market is projected to experience steady growth, reaching approximately USD 5.0 billion by 2028, with an estimated growth rate of 3.7%, supported by the continued development of new haptic technologies [2] as shown in Figure 1. The objective of this study is to offer a thorough comprehension of the incorporation of haptic technology into network applications through an analysis of technological developments, a range of use-case scenarios from different industries, challenges and constraints, and potential future directions. The study intends to evaluate and comprehend the effects of current advancements in haptic feedback, including device miniaturization and enhanced actuator technologies, on user experiences. It also considers haptic technology's wider applications and future advances, in addition to addressing technical and practical issues like compatibility and latency.

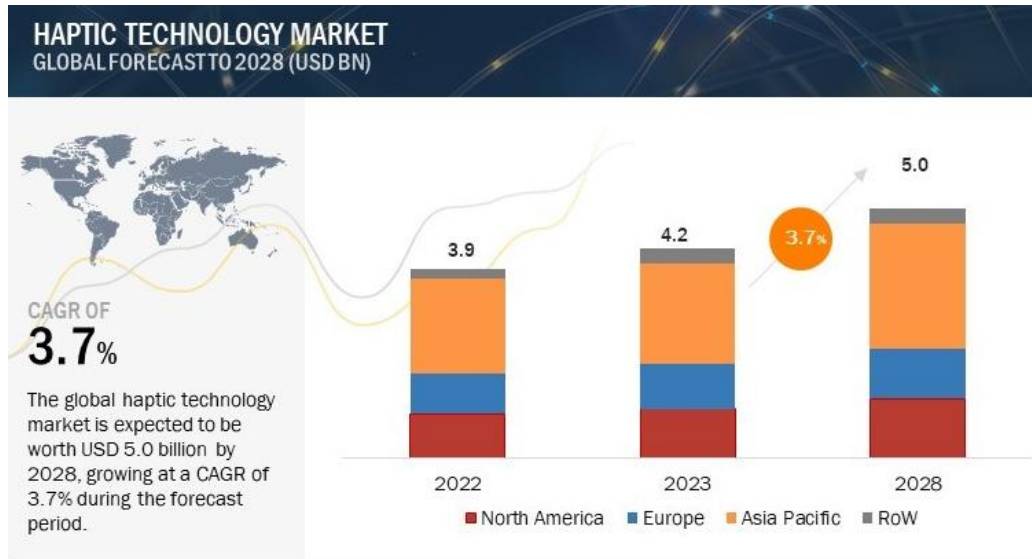


Figure 1. Global Haptic Technology Market Forecast to 2028 [2]

The primary objective of this research is to analyse and synthesize academic publications, research journals, articles and technical reports on how to incorporate haptic technology with network applications. The research comprises of a thorough review of existing literature to create a comprehensive review that highlights the current technology, challenges, new advances and future directions in this field. To get accurate data, real life case studies, methods and technological breakthroughs related to haptic technology have been examined and analysed. This has been done across different sectors and applications. This detailed analysis is important to allow new applications to emerge by evaluating technological advancements, use-case scenarios, challenges and future directions.

2. TECHNOLOGICAL ADVANCES IN HAPTIC FEEDBACK

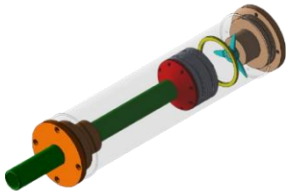
There have been many advances in haptic technology in recent years. Actuators, networked system integration and wearable haptic devices have improved every year, and this has lifted the quality and realism of tactile experiences. These improvements have changed how people interact with virtual world and AR. New technologies and discoveries in different fields cause more responsive and immersive experiences in many industries across the world.

2.1 Innovation in Actuator Technology

Haptic technology has improved significantly in many ways, where high-resolution tactile feedback systems can accurately replicate fine sensations like texture and shape. This has been possible due to innovation in actuators, which is important in haptic devices as it provides touch input to users through forces, vibration and movement. Actuators technology has improved the tactile feedback in haptic devices, which makes it essential to be used in various applications.

The improvements in actuator technology have significantly helped to enhance the quality and realism of haptic technology. This allows users to experience more realistic and engaging virtual environment by accurately simulating textures and shapes based on real life. For example, users can feel the curves and shape of a virtual object or how rough the surface of the object is as accurate as how it would be in reality. This can be achieved by the precision and accuracy of high-resolution actuators [3]. There are three main types of actuators used in haptic devices. The actuators are shown in Table 1, and it is compiled by thorough review of existing studies to help the understanding of the research.

Table 1. Types of Actuators using Haptic Technology

Actuator Type	Description	Key Development	Image
Electroactive Polymers (EAP) [4]	Actuators that deform in response to electrical stimulation, providing soft and flexible tactile feedback.	Improved durability and response time, enhanced tactile precision.	
Piezoelectric Actuators [5]	Generate vibrations by converting electrical signals into mechanical motion.	Increased resolution and force output, miniaturization for wearable devices.	
Magnetorheological Actuators [6]	Utilize magnetic fields to control the viscosity of a fluid, providing variable resistance.	Enhanced control and feedback accuracy, integration into robotic systems.	

2.2 Enhanced Interactivity through AR and VR

Haptic technology provides tactile input that can help with visual and audio stimulation. This stimulation can improve the interactivity in AR and Virtual Reality (VR). This additional stimulation makes the virtual interactions feel more realistic and engaging, which improves the user's sense of presence by providing immersive experience. Wearable haptic devices are important in creating these immersive experiences by allowing the users to interact and feel virtual objects with high level of realism which was not achievable before.

Wearable haptic devices such as gloves, vests, and suits provide tactile feedback for virtual objects and interactions, which enhance the user experience in augmented and VR [7]. These devices allow users to feel textures, shapes and forces as if they are present there and engaging with real-world objects and situations. This improves the sense of realism of virtual environment significantly.

2.3 Emerging Technologies and Prototypes

There have been many prototypes and technologies that are emerging, and this expands the range of networked applications. These advancements make haptic interactions more realistic and useful to users. This does not only help for technology industry, but also helps in various industries such as entertainment, education and medical industry.

For instance, one area of development which is promising is bio-inspired actuators that mimic human skin sensations. These actuators provide realistic and natural haptic experience by imitating complex tactile feedback which is found in human skin. Scientists have created actuators that can replicate responsiveness and sensitivity of

human skin, which provides detailed tactile feedback [8]. They use new materials and designs to develop actuators that can recreate different types of tactile experiences such as pressure, texture and temperature. Table 2 shows various usages of wearable haptic devices.

Table 2. Wearable Haptic Device Applications

Application	Description	Image
Virtual Training Simulations [9]	Trainees can practice skills in a virtual environment, receiving haptic feedback that mimics real-world sensations.	
Gaming [10]	Gamers can experience enhanced realism and immersion by feeling in-game actions, such as impacts and vibrations.	
Medical Training [11]	Medical professionals can perform virtual surgeries with tactile feedback that simulates real surgical procedures.	

Another improvement which is important to haptic technology is the use of adaptive algorithms. These algorithms can change the haptic input based on user's context and interaction patterns, which ensures that the haptic feedback provided is constantly relevant and suited to the user's current circumstances. Table 2 illustrates many applications for wearable haptic devices. Table 3 shows algorithms that adjust haptic input based on the scenario in which it is used, hence boosting the usefulness and relevancy of feedback [12]. The features of adaptive algorithms were derived through a qualitative synthesis of existing literature, involving a cross-comparison of several case studies that explore haptic systems.

Table 3. Features of Adaptive Algorithms

Feature	Description
Context-Awareness	Adjust feedback based on the specific use-case or environment
User Preferences	Learns and adapts to individual user preferences for a personalized haptic experience
Real-Time Adjustment	Modifies haptic output in real-time to ensure the feedback remains relevant and effective

As these technologies advance, they are likely to become more broadly integrated into everyday products and applications, fostering creativity and improving user experiences. By incorporating these innovations, researchers, developers, and business professionals can create new opportunities for haptic-enhanced network applications, resulting in more immersive, entertaining, and productive digital interactions.

3. USE-CASE SCENARIOS AND APPLICATIONS

Networks with haptic enhancement have been implemented in a variety of sectors. These uses highlight how haptic technology can revolutionize industries including healthcare, technology, entertainment, and telecommunications.

These networks increase accuracy, user experience, immersion, and communication through the integration of tactile feedback.

3.1 Medical Sector

Advanced training simulations, remote consultations, and complex surgeries are being made possible by haptic-enhanced networks, which are transforming the healthcare industry. These technologies are increasing access to healthcare services, improving patient outcomes, and boosting the accuracy and caliber of medical treatments. Haptic-enhanced networks find great applicability in remote surgical procedures. Using tactile input, surgeons can execute procedures remotely while maintaining exact motions and superior patient care [13]. Surgeons can feel the resistance and texture of tissues with haptic feedback, which makes remote procedures just as exact as those done in person.

Haptic feedback improves diagnostic procedures in telemedicine and makes realistic simulations possible for medical education [8]. During remote examinations, haptic interfaces enable clinicians to feel the resistance and texture of tissues, which enhances diagnostic precision. By simulating the tactile sensation of actual procedures, realistic haptic simulations improve medical personnel' readiness and abilities through training.

In rehabilitation physiotherapy, haptic interfaces are essential because they improve patient involvement and speed up the recovery of motor skills. Based on Figure 2 [12], the market for haptic assisted physical therapy is anticipated to expand at a Compound Annual Growth Rate (CAGR) of 7.21% from 2023 to 2031. Haptic feedback offers interactive and responsive rehabilitation exercises that promote patient involvement. Customized haptic exercises increase therapy outcomes by assisting patients in regaining motor skills more successfully.

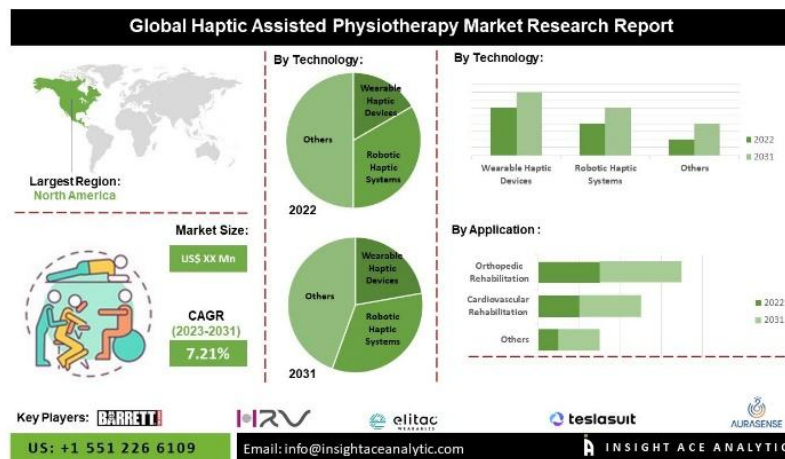


Figure 2. Haptic Assisted Physiotherapy Market Research Report

3.2 Technology Sector

In the technology business, haptic feedback is critical for enhancing user experiences on a wide range of devices and apps. The use of tactile reactions in consumer electronics and industrial applications is changing the way people interact with technology. Consumer electronics routinely use haptic feedback to improve usability and user experience [14]. Tactile feedback makes user interactions with touch screens more responsive and intuitive. This includes sensations for notifications and haptic feedback for virtual buttons. These devices keep users informed and engaged without the need to check their screens constantly. They use haptic feedback to alert users about messages, reminders, and health updates.

In the industrial sector, haptic feedback improves productivity and safety in hazardous environments through remote operations and maintenance [15]. Haptic feedback lowers the risk of accidents by letting personnel control machinery from a safe distance. This is particularly useful in industries like mining, nuclear power, and oil and gas. Tactile responses provide instant feedback on the equipment's condition, which increases worker accuracy and

efficiency. This leads to less downtime and helps in spotting problems early. Wearable technology with haptic feedback enhances how users interact by offering immediate, intuitive bodily responses [16], [17]. Wearable devices sewn into clothing give haptic feedback for notifications and health monitoring. This lets users receive information quietly and easily. Table 4 contains haptic-enhanced applications in technology sector.

Table 4. Haptic-Enhanced Applications in Technology

Application	Description	Impact	Image
Consumer Electronic [18]	Enhances usability of smartphones, smartwatches, fitness trackers	Improved user experience and engagement	
Industrial Applications [19]	Enables safe and efficient remote operations and maintenance	Increased safety and operational efficiency	
Wearable Technology [20]	Provides intuitive and immersive experiences in smart clothing, AR, VR	Enhanced user interaction and realism	

3.3 Entertainment Sector

The entertainment industry is increasingly using haptic technology to create more realistic and immersive experiences, especially in gaming and VR. Haptic technology is transforming the gaming sector by giving players tactile feedback that mimics real-world experiences. This helps the players by improving their engagement and realism by enhancing the immersive experience [17]. Users can use haptic devices to interact with the virtual environment and feel connected by sensing forces, textures and shapes. For example, if a player is pulling a bowstring in the game, the player would feel the texture of the string that they touch and the resistance of the string when they pull it. Gamers are required to wear haptic vests to replicate collisions, explosions and other environmental effects and various in-game actions. This improves the overall gaming experience and adds a realistic dimension.

Haptic technology in virtual environment is essential in creating realistic and engaging virtual worlds. Haptic technology improves tactile sensations with visual and auditory cues [21]. This helps to improve user's sense of presence in games. Haptic feedback also adds realism to VR environment by simulating real-world sensations, which improves the immersive experience for training, educational simulations and virtual tours in games.

In AR, haptic feedback improves the user interactions by providing tactile responses for virtual elements in game as accurate as in the real world. This is helpful for applications which require interactive storytelling and virtual displays. This haptic feedback improves realism by allowing the users to feel virtual objects and presentation. For example, users can touch the shapes and feel the corners and edges of a historical artifact and feel its surface. Haptic feedback can also improve storytelling by giving tactile clues related to the events in the story. This adds a sense of emotion and improves the overall experience for users. Table 5 shows haptic-enhanced applications in entertainment industry.

3.4 Telecommunication Sector

The integration of haptic technology in telecommunication networks creates realistic and engaging telepresence. It changes how people interact in virtual environments. Haptic technology provides realism in telepresence by simulating physical interactions through tactile feedback. This addition in realism allows users to feel physically

present in virtual meetings and social gatherings, which improves the engagement and communication between users who are on-site and who are joining virtually [22]. This technology can boost teamwork by giving team members the same tactile sensations. For example, users can feel the pressure of pressing a virtual button or the texture of a shared virtual object. This shared experience improves coordination and collaboration skills. Haptic feedback also helps skill development and performance by offering learners realistic tactile sensations. This can be used for specific activities during remote training sessions.

Table 5. Haptic-Enhanced Applications in Entertainment

Sector	Application	Impact
Gaming	Haptic Gloves and Vests	Enhanced interaction, realism, and engagement
VR	Environmental Interaction	Increased realism and presence
AR	Interactive Exhibits	Improved engagement and educational value

Networks with haptic features are essential for improving remote teamwork. Since haptic technology provides tactile feedback, these networks reduce geographical distances and practice more engaged and cooperative interactions. By enhancing virtual social experiences with tactile feedback, haptic-enhanced networks also boost social interactions. Even when they are far distant, users can experience a sensation of presence and proximity because of this technology, according to Figure 3 [23]. In virtual social gatherings, haptic feedback can replicate the sensation of a hug, handshake, or touch, enhancing the personal and meaningful nature of these interactions. This capacity is particularly helpful for preserving social ties in partnerships that are long-distance. To improve user engagement and pleasure, haptic technology can be incorporated into social media platforms to deliver tangible responses to likes, comments, and other interactions.

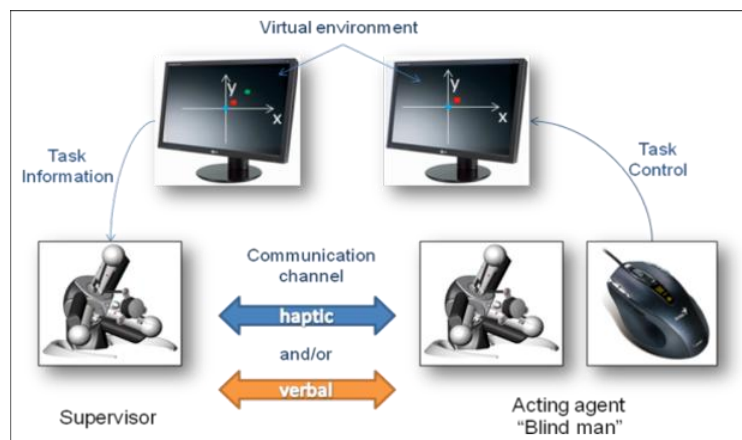


Figure 3. Haptic Technology in Telecommunication Virtual Environment

Every industry has its own unique way of using haptic-enhanced network applications in their sectors. Haptic technology has surely been helpful in building and improving the sector's practical implications and procedures and plays a significant role in enhancing the experience of users who consume the services of all these sectors. Below is a brief comparison of use-case scenarios of 4 main industries that consume haptic technology.

4. CHALLENGES AND LIMITATIONS

The usage of haptic technology in network applications causes few technical challenges. It is important to overcome these significant issues to properly integrate haptic feedback into these systems. The expensive cost of haptic

devices further restricts accessibility. The deployment procedure is made more complex by the need for user adaptation and training. Maintaining user confidence also requires addressing privacy and security concerns related to haptic data.

4.1 Technical Complexity and Integration

Technical complexity in integrating haptic feedback into application is a crucial challenge in adapting haptic technology effectively. To ensure tactile reactions occur in real time, low latency connectivity and strong synchronization among different network systems is important and must be prioritized [24]. In certain areas like VR or remote surgery, high latency can affect the quality of haptic interactions massively. This might frustrate users and reduce the effectiveness of using this technology. Haptic devices and network systems should be kept in sync for clear and consistent feedback which can reduce its complexity. Any delays or inconsistencies can ruin the user experiences and weaken the effectiveness of haptic applications. While some research used real-time testbeds or network emulation tools to assess latency under different network settings, others presented simulation-based results that emphasised latency limits that are essential for preserving consistent haptic contact.

Another major issue is compatibility between haptic devices and different platforms or operating systems. The smooth installation and operation of haptic devices in various contexts may be hampered by the absence of defined protocols. Haptic technology requires very complex protocols, and the users are required to understand and acquire certain software or hardware to ensure compatibility. An example of a complex augmented multimodal haptic feedback system compatible with IoT platform is shown in Figure 4 [25].

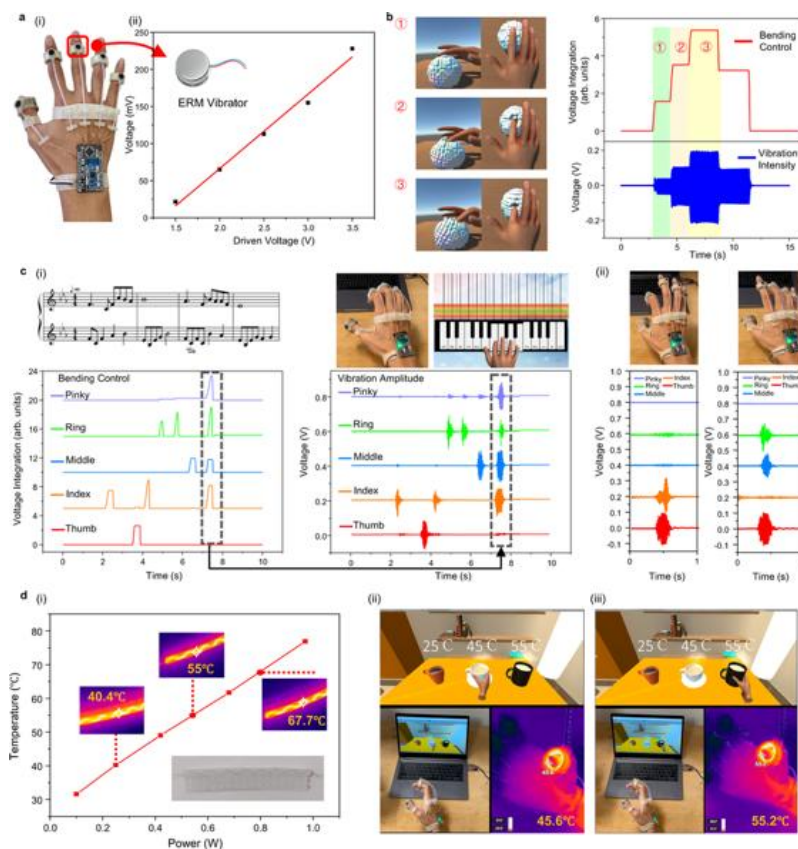


Figure 4. An IoT-Compatible Augmented Multimodal Haptic Feedback System

It is common for haptic devices to have to interact with multiple platforms, each with different specs and needs. Ensuring interoperability among various platforms can be resource-intensive and difficult. The lack of standardized protocols for integrating haptic feedback makes it harder for different systems and devices to work together. Table 6 shows a comparison of four different industries that use haptic technology.

Table 6. Comparison Between 4 Industries using Haptic Technology

Industry	Methodology	Advantages	Limitations	Results
Medical and Healthcare [26]	Experimental design, Statistical analysis	Improved accuracy in medical procedures	Small sample sizes, Limited generalizability	Significant improvements in surgical precision, Treatment outcomes
Technology and Engineering [27]	Development of prototypes, User testing	Enhanced user experience, Real-time data processing	High development cost, Hardware limitations	Successful demonstration of prototypes, Improved user interaction
Entertainment and Art [28]	Design and development of interactive experiences	Enhanced immersion, User engagement	Technical constraints, Content production challenges	Improved user satisfaction, Immersive entertainment experiences
Telecommunication and Network [29]	Literature review, Case studies and examine real scenarios	Improved network efficiency, Enhanced communication	Limited scope of case studies, Varying methodologies	Increased network reliability, Optimized communication

4.2 Bandwidth and Latency Requirements for Haptic Applications

Implementing real-time haptic feedback in networked systems has challenges related to latency and bandwidth. Round-Trip Time (RTT), packet delay variation and end-to-end transmission delay are few ways to accurately measure latency. Haptic data transfer requires a certain amount of bandwidth and low latency to provide tactile input effectively in real time [30]. High-fidelity haptic feedback requires high number of data transfers, and the bandwidth must be sufficient to process the data without delays or data loss. Low latency is essential for haptic applications which require accurate timing and synchronization. Any delays or lags can disrupt the haptic experience which can cause incorrect information, which would affect the output and overall user experience.

Wireless and mobile networks are mainly affected by latency and capacity issues as it is very unpredictable [31]. Changes in bandwidth availability are common in wireless networks, impacting the reliability of haptic delivery. Mobile networks can introduce delays because of signal interference and network congestion, making real-time haptic feedback difficult. Tackling these challenges means improving the data transfer method [32]. By effectively compressing haptic data, it is possible to maintain the quality of tactile feedback while reducing the required transmission bandwidth. To maintain low responsiveness and latency, algorithms might prioritize haptic data over less critical network traffic. To ensure a consistent user experience, adaptive streaming techniques vary the strength of haptic feedback dependent on the network's condition. Table 7 shows the bandwidth and delay requirements.

Table 7. Bandwidth and Latency Requirements for Haptic Applications

Application	Required Bandwidth	Latency Requirement	Impact of Insufficient Bandwidth/Latency
Remote Surgery [33]	High	<10 ms	Delayed response, reduced precision
VR Gaming [34]	Moderate	<20 ms	Disrupted immersion, inaccurate feedback
Telemedicine Consultations [29]	Moderate	<30 ms	Degraded interaction quality, delayed diagnostics

4.3 Cost and Accessibility

The implementation of haptic-enhanced network applications offers substantial cost and accessibility concerns. The cost of haptic devices and network infrastructure might be prohibitively expensive, especially for consumer

applications and small businesses [35]. Sophisticated haptic devices may provide realistic tactile input, but developing and manufacturing them can be expensive. These costs may be too expensive for budget-conscious enterprises and individuals. Haptic-Enhanced network installation necessitates a dependable infrastructure with high bandwidth and low latency. Significant financial investments may be required to establish new infrastructure or upgrade existing networks.

Another key issue is maintaining accessibility across various socioeconomic backgrounds [36]. Exorbitant costs may limit the availability of haptic technology to both individuals and institutions in less fortunate countries. Because haptic technologies are expensive, lower-income people may have limited access to cutting-edge medical, educational, and recreational applications, increasing existing economic disparities. It's tough to expand haptic-enhanced apps without losing quality or cost. To ensure consistent performance across different environments and user types, innovative design and distribution tactics are required. The cost breakdown which reflects a general approximation based on range of pricing trends observed across multiple references is shown in Table 8.

Table 8. Cost Breakdown of Haptic-Enhanced Network Applications [37]

Component	Cost Range	Description
Haptic Devices	\$500 - \$5,000	Includes haptic gloves, vests, and interfaces
Network Upgrades	\$10,000 - \$100,000	Costs for enhancing network infrastructure
Software Development	\$50,000 - \$500,000	Development of compatible software and applications

To improve the accessibility of haptic-enhanced network applications, a variety of cost-cutting strategies may be implemented while maintaining quality and dependability. The cost of haptic devices per unit can be reduced as production quantities increase. By encouraging wider use through subsidies or other incentives, demand may be boosted over time while prices are decreased. Open-source software development can save software expenses and increase creativity in haptic application development. Community-driven initiatives can produce affordable solutions that serve a larger population. Governments, businesses, and nonprofits working together can provide funding for infrastructure improvements and haptic technology subsidies for use in healthcare and education.

5. FUTURE DIRECTIONS AND OPPORTUNITIES

Many sectors are expected to change because of haptic technological advancements, which offer more immersive and sensitive experiences. Expansion into new application areas, motivated by interdisciplinary cooperation, promises to enhance human-machine interactions and tackle a range of challenges. Prioritizing user-centric design will provide seamless integration in both personal and professional settings. Resolving ethical and legal concerns is also necessary for fostering confidence and proper deployment.

5.1 Advancements in Haptic Technology

Future developments in haptic technology have the potential to revolutionize networked applications in a variety of sectors, including education, healthcare, and entertainment. The expected advancements in haptic technology are examined in this section along with how they can affect user experiences. The incorporation of state-of-the-art materials that can offer more subtle tactile feedback is one of the main areas of improvement [24]. These materials, which include electroactive materials and smart polymers, can more accurately and realistically replicate a variety of tactile sensations. It is anticipated that haptic interactions will become more realistic as force feedback technology advancements continue [38]. With the ability to provide accurate force and torque feedback, these technologies will improve the realism of remote and virtual interactions. Accurately simulating real-world forces with improved force feedback systems increases the realism of virtual. Enhanced force feedback in medical simulations can give practitioners more lifelike training scenarios, enhancing their proficiency and readiness.

A broader audience can benefit from haptic feedback by incorporating smaller, more portable devices into wearable and smartphone programs. Small haptic devices that give tactile feedback for warnings and user interactions can be

included in tablets and smartphones. Wearable haptic devices such as haptic vests and gloves can give immersive experiences in VR and gaming, respectively. Figure 5 [39] illustrates a tiny haptic device.

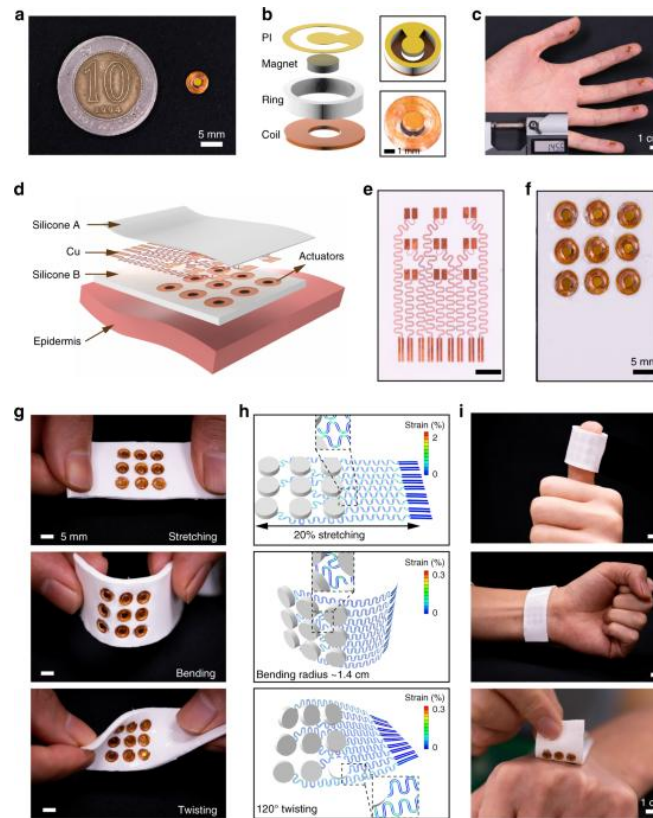


Figure 5. Miniaturization of Mechanical Actuators [39]

5.2 Expansion into New Application Areas

As haptic technology extends into new application domains, it can significantly improve human-machine interactions and solve a variety of social concerns. Haptic technology can considerably improve AR applications by delivering tactile input that increases spatial awareness [40]. This can be very useful for navigation, design, and interactive training simulations. Haptic feedback, which provides tactile signals of obstacles and directions, can assist users in navigating complicated environments. Haptic feedback in AR design improves realism and accuracy by allowing designers to feel textures and resistance.

Haptic feedback may be an important part of industrial training simulators, delivering realistic tactile sensations that improve learning and skill development [41]. Haptic feedback can simulate dangerous situations, letting trainees practice their responses without facing real risks. Trainees can interact with virtual machinery and tools, feeling resistance and movement, which gives them hands-on experience in a safe environment. Haptic technology is regularly used in treatments and rehabilitations to help patients to regain their motor skills and sensory functions. Patients who need assistance can exercise and rebuild their strength and mobility with haptic devices that provide resistance and guidance. Tactile feedback can assist patients to regain their sense of touch and awareness of body positions.

Haptic technology can make travelling more immersive by including tactile sensation to virtual worlds. Visitors can feel textures of historic artifacts and natural landscapes, which enhances their virtual travel experience. Haptic feedback simulates environmental features such as the feeling of sand and air, which makes virtual tours more authentic and realistic. Table 9 shows examples of haptic enhanced virtual tourism.

Table 9. Examples of Haptic-Enhanced Virtual Tourism

Virtual Experience	Haptic Feedback	Benefit
Historical Artifacts	Feeling textures and shapes	Enhanced cultural and educational experience
Natural Landscapes	Simulating environmental conditions	Increased realism and engagement

5.3 Interdisciplinary Collaboration

Collaboration across different fields would impact on the future of haptic technology and its development significantly. Researchers can broaden their understanding of human sensory perception by sharing knowledge and methods that they learned and studied from various areas. This approach can lead to user-friendly interface that meets the goals of different applications and improves the algorithm of haptic feedback. Computer science is essential for creating complex software and algorithms that deliver accurate and responsive haptic feedback [24]. Specific algorithms are required to ensure low latency and high fidelity for real-time processing of haptic feedback transmission. New technology would also help to create realistic virtual environments to test and improve haptic input, output and overall performance.

It is crucial to understand human sensory perception to design haptic devices that offer clear and effective feedback [42]. Current research in human psychology offers insights into how people interpret different tactile signals. This is important to create effective haptic feedback systems. The convergence of these diverse fields through interdisciplinary collaboration can lead to significant advancements in haptic technology. By combining knowledge from several fields, more comprehensive solutions that cover a range of haptic technology-related issues are produced. By utilizing the advantages of each discipline, collaborative research can quicken the rate of invention.

These interdisciplinary contributions will result in growth in the haptic technology market. Based on Figure 6 [43], Haptic Technology Market is Expanding at 11.14% Growth by 2030. The APAC haptic technology market is anticipated to lead the industry between 2021 and 2026. An important factor driving market expansion is raising disposable income, which has led to a surge in the use of consumer electronics.

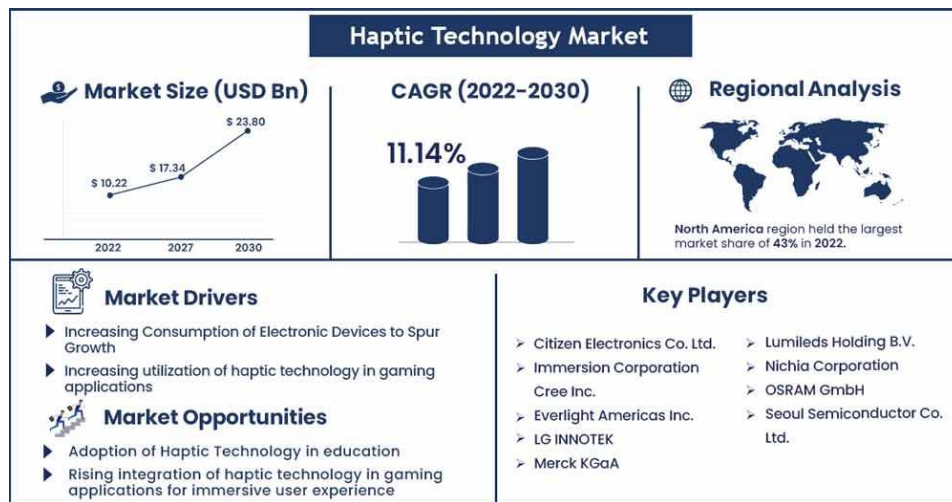


Figure 6. Haptic Technology Market by 2030

Multidisciplinary cooperation is necessary to keep haptic technology evolving. Through the amalgamation of expertise and techniques from computer science, materials science, psychology, and neuroscience, scientists may create increasingly advanced and efficient haptic systems. These cooperative initiatives aim to improve user experiences, broaden the scope of haptic applications, and quicken the rate of innovation in network applications that are enhanced by haptics.

6. RESEARCH METHODOLOGY

This study adopts a systematic literature review methodology to investigate the integration of haptic technology into network applications. The review was set up to guarantee a thorough, trustworthy, and impartial summary of pertinent research findings that have been published throughout the previous 20 years.

6.1 Literature Identification and Selection

Reputable academic databases and search engines, such as Google Scholar, IEEE Xplore, Springer, ScienceDirect, and ResearchGate, were used to find relevant literature. The Tun Hussein Onn Library and other university resources provided additional access. These platforms were chosen for their wide coverage of scientific and technical papers related to networking and haptic feedback. The entire methodology process is summarized in Figure 7.

The search focused on specific keywords, looking for phrases like "haptic technology," "network applications," "tactile feedback systems," and "real-time communication." Publications from 1998 to 2024 were considered to provide a complete view of the development of haptic systems in networking contexts

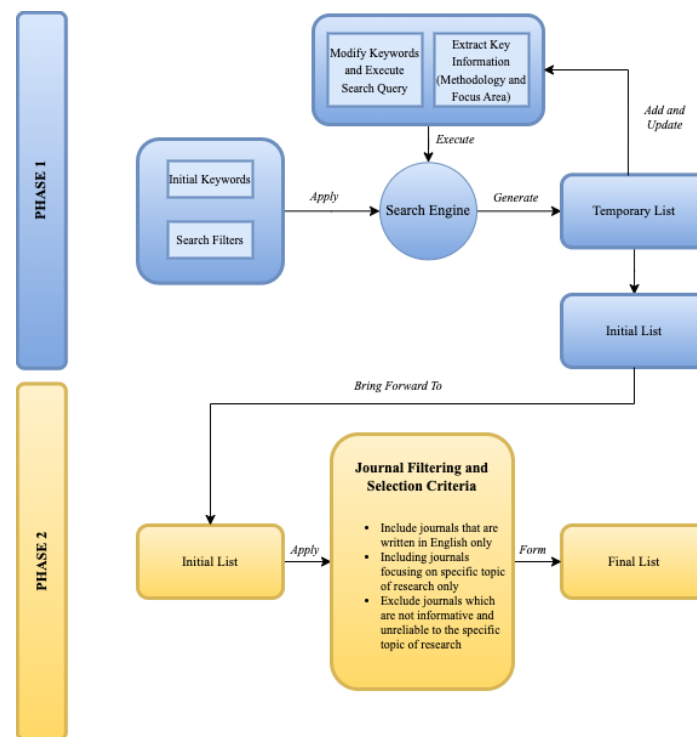


Figure 7. Review and Research Methodology Conducted in this Paper

6.2 Inclusion and Exclusion Criteria

An initial pool of 170 sources was identified through the literature search. These sources included scholarly reports, white papers, conference proceedings, and peer-reviewed journal articles. The sources were screened based on predefined inclusion criteria:

- Publications written in English;
- Peer-reviewed journal articles and relevant conference proceedings;
- Publications within the defined publication period;

- Studies directly addressing the use, development, or application of haptic technology in network-based systems.

The initial screening was conducted based on the title, abstract, and keywords. Sources that did not meet the inclusion criteria or were found to be irrelevant, duplicated, or insufficiently related to the scope of this review were excluded. The remaining studies underwent a more detailed full-text assessment based on their technical contribution and thematic relevance. Following the screening and full-text review process, the most relevant sources were retained for the final synthesis and citation in this paper.

6.3 Thematic Review and Analysis

A thematic analysis of the selected literature was conducted, focusing mainly on two areas: (i) the technical aspects of haptic integration, including latency, synchronization, network constraints, and real-time response mechanisms, and (ii) real-world applications in fields like collaborative robotics, VR, online education, and remote surgery.

To extract key information, methods, constraints, conclusions, and technological perspectives, each article underwent a thorough review. These findings were combined to identify trends, common issues, and important advancements. The analysis also compared various research methods to shared challenges, such as adaptive feedback systems and reducing latency. By recognizing these themes and linking them, the review showed how haptic technologies are evolving with better networking infrastructure and driving innovation in network applications that use haptics.

7. DISCUSSION AND CONCLUSION

A new era of digital interaction has begun with the introduction of haptic technology in network applications. This change has transformed the user experience across various industries. This research examines how haptic feedback alters applications in healthcare, technology, entertainment, telecommunications, and education. By breaking down sensory barriers, haptic technology makes digital and physical environments more immersive, natural, and responsive. The constant development of haptic technology, which includes force feedback systems, miniature devices and fresh materials has improved realism and overall experience of virtual interactions. The need and usage of haptic interfaces in consumer and professional applications have grown significantly due to new technology that allows more sensitive and detailed touch inputs.

There are many applications that use haptic technology, and every industry improves significantly due to benefits of using haptic technology. For example, the usage of haptic technology has improved telemedicine consultations. On top of that, precision and accuracy in remote operations have increased in the medical industry. The technology industry uses haptic technology to improve user interfaces to provide consumers with a responsive and interactive system. In entertainment industry, haptic technology has improved the way consumers consume digital information such as films and games as adding haptic feedback into a VR application makes it more realistic and interactive. Education industry has also benefited from haptic technology as it provides hands-on experiences and realistic simulations. For example, haptic technology has enhanced medical training simulations and improves accuracy of diagnosis, which leads to better outcomes for patients and a more effective medical education system.

Despite its transformative potential, there are many challenges to implement haptic-enhanced network applications effectively. Technical complexity is a significant issue as good synchronization and low-latency transmission is crucial in implementing haptic technology. The quality and consistency of haptic devices can be affected by bandwidth and latency issues, especially in wireless and mobile networks. Advanced haptic devices and the infrastructure to produce good quality haptic devices may be too expensive, which limits the access for individuals and organizations which low budget to spend. Implementation of haptic technology requires user training to ensure users are aware of the potential of haptic devices. Privacy and security concerns on collecting and sharing haptic data must be informed to users to build trust and comply with data protection laws.

This study includes a substantial amount of research on haptic-enhanced network applications, but there are several limitations. Firstly, due to lack of resources there were no primary experiments or user studies conducted. This study relies mainly on secondary data. This limits the paper's ability to provide empirical evidence for technical claims, or

the applications results that is discussed. Secondly, different studies had different access to comprehensive technical specifications and cost information, which sometimes results in general data. Finally, the review may have missed important insights published in other languages or restricted repositories because it mainly concentrated on English-language sources and easily accessible academic databases. Future work may benefit from incorporating experimental evaluations, broader language coverage, and a deeper analysis of emerging real-world deployments.

Haptic-enhanced network applications have a promising future ahead of them, with plenty of room for development and expansion. To accelerate innovation and incorporate ideas from computer science, materials science, psychology, and neuroscience, interdisciplinary collaboration must continue [44]. Haptic interfaces will become more customized and intuitive as user-centric design advances, leveraging AI and machine learning to adapt in real time to changing ambient circumstances and user preferences [45], [46]. To guarantee responsible deployment and preserve user confidence, ethical and regulatory issues need to be considered in advance [47]. In order to equip the upcoming generation of professionals to use haptic technology efficiently in a variety of disciplines, educational and training activities will be crucial [48].

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CONFLICT OF INTERESTS

No conflict of interest was disclosed.

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Our publication ethics follow The Committee of Publication Ethics (COPE) guideline. <https://publicationethics.org/>

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

- [1] S. Saju, M. S. Priyadharsini, and M. A. Sriram "A novel test-bed for immersive and interactive broadcasting production using augmented reality and haptics," *IEICE transactions on information and systems*, vol. 89, no. 1, pp. 106-110, 2006, doi: 10.1093/ietisy/e89-d.1.106
- [2] S. Saju, M. S. Priyadharsini, and M. A. Sriram, "Review of 6G Communication in Haptic Technology," *Advances in Dynamical Systems and Applications*, vol. 17, no. 1, pp. 247-256, 2022.

- [3] S. Pyo, J. Lee, K. Bae, S. Sim, and J. Kim, "Recent progress in flexible tactile sensors for human-interactive systems: from sensors to advanced applications," *Advanced Materials*, vol. 33, no. 47, p. 2005902, 2021, doi: 10.1002/adma.202005902
- [4] Y. Bar-Cohen, and I. A. Anderson, "Electroactive polymer (EAP) actuators—Background review," *Mechanics of Soft Materials*, vol. 1, no. 1, p. 5, 2019, doi: 10.1007/s42558-019-0005-1
- [5] X. Gao, J. Yang, J. Wu, X. Xin, Z. Li, and X. Yuan "Piezoelectric actuators and motors: materials, designs, and applications," *Advanced Materials Technologies*, vol. 5, no. 1, p. 1900716, 2020, doi: 10.1007/978-1-4613-1463-9_3
- [6] J. Xu, Y. Li, L. Xu, C. Peng, S. Chen, and J. Liu, "A multi-mode rehabilitation robot with magnetorheological actuators based on human motion intention estimation," *IEEE transactions on neural systems and rehabilitation engineering*, vol. 27, no. 10, pp. 2216-2228, 2019, doi: 10.1109/tnsre.2019.2937000
- [7] Y. Qiao, Q. Zheng, Y. Lin, Y. Fang, Y. Xu, and T. Zhao, "Haptic communication: Toward 5G tactile internet," in *2020 Cross Strait Radio Science & Wireless Technology Conference (CSRSWTC)*, 2020: IEEE, pp. 1-3, doi: 10.1109/csrswtc50769.2020.9372659
- [8] P. B. Shull, and D. D. Damian, "Haptic wearables as sensory replacement, sensory augmentation and trainer—a review," *Journal of neuroengineering and rehabilitation*, vol. 12, pp. 1-13, 2015, doi: 10.1186/s12984-015-0055-z
- [9] M. Vassallo, "The Role of Force Feedback and Vibrotactile Feedback in Learning and Retaining Procedural and Factual Knowledge in an Immersive Virtual Training Simulation," 2023.
- [10] A. Brigden, "Towards a Framework Using Sonic Expression as a Gaming Mechanic for Immersive Playing Experiences in VR Games," Goldsmiths, University of London, 2024.
- [11] K. Rangarajan, H. Davis, and P. H. Pucher, "Systematic review of virtual haptics in surgical simulation: a valid educational tool?," *Journal of surgical education*, vol. 77, no. 2, pp. 337-347, 2020, doi: 10.1016/j.jsurg.2019.09.006
- [12] InsightAce Analytic. (2025, June 10). Patient-generated health data market size, share & trends analysis report by data type, end user, region, and segment forecasts, 2025–2034. <https://www.insightaceanalytic.com/report/patient-generated-health-data-market-/2319>
- [13] D. Shabir, N. Abdurahiman, J. Padhan, M. Anbatawi, M. Trinh, and S. Balakrishnan, "Preliminary design and evaluation of a remote tele-mentoring system for minimally invasive surgery," *Surgical endoscopy*, vol. 36, no. 5, pp. 3663-3674, 2022, doi: 10.1007/s00464-022-09164-3
- [14] B. Chebbi, D. Lazaroff, and P. X. Liu, "A collaborative virtual haptic environment for surgical training and tele-mentoring," *International Journal of Robotics & Automation*, vol. 22, no. 1, p. 69, 2007, doi: 10.2316/journal.206.2007.1.206-1007
- [15] G. M. Minopoulos, V. A. Memos, K. D. Stergiou, C. L. Stergiou, and K. E. Psannis, "A medical image visualization technique assisted with AI-based haptic feedback for robotic surgery and healthcare," *Applied Sciences*, vol. 13, no. 6, p. 3592, 2023, doi: 10.3390/app13063592
- [16] G. D'Souza, S. R. Tewari, T. Troy, J. Webster-Cyriaque, D. J. Wiley, and C. D. Lahiri, "Oncogenic oral human papillomavirus clearance patterns over 10 years," *Cancer Epidemiology, Biomarkers & Prevention*, vol. 33, no. 4, pp. 516-524, 2024.
- [17] L. A. Coker, "Development of a Haptically Enhanced Digital Application Magic spells Designed to Aid in Vocabulary Acquisition for Learners with Dyslexia," Sam Houston State University, 2022.

- [18] A. Henriksen, M. Haugen Mikalsen, A. Z. Woldaregay, M. Muzny, G. Hartvigsen, and L. A. Hopstock "Using fitness trackers and smartwatches to measure physical activity in research: analysis of consumer wrist-worn wearables," *Journal of medical Internet research*, vol. 20, no. 3, p. e110, 2018, doi: 10.2196/jmir.9157
- [19] J.-Q. Li, F. R. Yu, G. Deng, C. Luo, Z. Ming, and Q. Yan, "Industrial internet: A survey on the enabling technologies, applications, and challenges," *IEEE Communications Surveys & Tutorials*, vol. 19, no. 3, pp. 1504-1526, 2017, doi: 10.1109/comst.2017.2691349
- [20] S. E. Alshaal, S. Michael, A. Pamporis, H. Herodotou, G. Samaras, and P. Andreou, "Enhancing virtual reality systems with smart wearable devices," in *2016 17th IEEE International Conference on Mobile Data Management (MDM)*, 2016, vol. 1: IEEE, pp. 345-348, doi: 10.1109/mdm.2016.60
- [21] P. Payeur, C. Pasca, A.-M. Cretu, and E. M. Petriu, "Intelligent haptic sensor system for robotic manipulation," *IEEE Transactions on Instrumentation and Measurement*, vol. 54, no. 4, pp. 1583-1592, 2005, doi: 10.1109/imtc.2004.1351045
- [22] G. S. Giri, Y. Maddahi, and K. Zareinia, "An application-based review of haptics technology," *Robotics*, vol. 10, no. 1, p. 29, 2021, doi: 10.3390/robotics10010029
- [23] H. H. King, B. Hannaford, J. Kammerl, and E. Steinbach, "Establishing multimodal telepresence sessions using the session initiation protocol (sip) and advanced haptic codecs," in *2010 IEEE Haptics Symposium*, 2010: IEEE, pp. 321-325, doi: 10.1109/haptic.2010.5444637
- [24] R. Raisamo, K. Salminen, J. Rantala, A. Farooq, and M. Ziat, "Interpersonal haptic communication: review and directions for the future," *International journal of human-computer studies*, vol. 166, p. 102881, 2022, doi: 10.1016/j.ijhcs.2022.102881
- [25] B. Takač, A. Chellali, C. Dumas, I. Milleville, C. Grosdemouge, and C. G. Cao, "Haptic communication for a 2D pointing task in a virtual environment," in *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 2011, vol. 55, no. 1: SAGE Publications Sage CA: Los Angeles, CA, pp. 2168-2172, doi: 10.1037/e578902012-461
- [26] M. Motaharifar *et al.*, "Applications of haptic technology, virtual reality, and artificial intelligence in medical training during the COVID-19 pandemic," *Frontiers in Robotics and AI*, vol. 8, p. 612949, 2021, doi: 10.3389/frobt.2021.612949
- [27] A. Palacios-Ibáñez, M. Alonso-García, M. Contero, and J. D. Camba, "The influence of hand tracking and haptic feedback for virtual prototype evaluation in the product design process," *Journal of Mechanical Design*, vol. 145, no. 4, p. 041403, 2023, doi: 10.1115/1.4055952
- [28] M. Paterson, "On haptic media and the possibilities of a more inclusive interactivity," *New Media & Society*, vol. 19, no. 10, pp. 1541-1562, 2017, doi: 10.1177/1461444817717513
- [29] R. Gupta, S. Tanwar, S. Tyagi, and N. Kumar, "Tactile internet and its applications in 5G era: A comprehensive review," *International Journal of Communication Systems*, vol. 32, no. 14, p. e3981, 2019, doi: 10.1002/dac.3981
- [30] M. McLaughlin, A. Rizzo, Y. Jung, W. Peng, S. Yeh, and W. Zhu, "Haptics-enhanced virtual environments for stroke rehabilitation," *Proc. IPSI*, 2005.
- [31] Z. Sun, M. Zhu, X. Shan, and C. Lee, "Augmented tactile-perception and haptic-feedback rings as human-machine interfaces aiming for immersive interactions," *Nature communications*, vol. 13, no. 1, p. 5224, 2022, doi: 10.1038/s41467-022-32745-8
- [32] A. El Saddik, "The potential of haptics technologies," *IEEE instrumentation & measurement magazine*, vol. 10, no. 1, pp. 10-17, 2007, doi: 10.1109/mim.2007.339540

- [33] R. V. Patel, S. F. Atashzar, and M. Tavakoli, "Haptic feedback and force-based teleoperation in surgical robotics," *Proceedings of the IEEE*, vol. 110, no. 7, pp. 1012-1027, 2022, doi: 10.1109/jproc.2022.3180052
- [34] C. N. Enebechi, "Impact of Variability of Haptic Feedback in Virtual Reality (VR) During Task Performance," Purdue University, 2024.
- [35] M. Oparin, and M. Eid, "Analysis of high-rate wireless links for tele-haptics applications," in *2017 International Conference on Computer and Applications (ICCA)*, 2017: IEEE, pp. 169-173, doi: 10.1109/comapp.2017.8079744
- [36] G. Minopoulos, G. Kokkonis, K. Psannis, and Y. Ishibashi, "A survey on haptic data over 5G networks," *International Journal of Future Generation Communication and Networking*, 2019, doi: 10.33832/ijfgcn.2019.12.2.04
- [37] T. Novacek, and M. Jirina, "Overview of controllers of user interface for virtual reality," *PRESENCE: Virtual and Augmented Reality*, vol. 29, pp. 37-90, 2020, doi: 10.1162/pres_a_00356
- [38] F. Danieau, A. Lécuyer, P. Guillotel, J. Fleureau, N. Mollet, and M. Christie, "Enhancing audiovisual experience with haptic feedback: a survey on HAV," *IEEE transactions on haptics*, vol. 6, no. 2, pp. 193-205, 2012, doi: 10.1109/toh.2012.70
- [39] Y. Tian, S. Raghuraman, T. Annaswamy, A. Borresen, K. Nahrstedt, and B. Prabhakaran, "H-TIME: haptic-enabled tele-immersive musculoskeletal examination," in *Proceedings of the 25th ACM international conference on Multimedia*, 2017, pp. 137-145, doi: 10.1145/3123266.3123395
- [40] D. Li *et al.*, "Miniaturization of mechanical actuators in skin-integrated electronics for haptic interfaces," *Microsystems & nanoengineering*, vol. 7, no. 1, p. 85, 2021, doi: 10.1038/s41378-021-00301-x
- [41] C. Bermejo, and P. Hui, "A survey on haptic technologies for mobile augmented reality," *ACM Computing Surveys (CSUR)*, vol. 54, no. 9, pp. 1-35, 2021, doi: 10.1145/3465396
- [42] J. Cha, M. Eid, L. Rahal, and A. El Saddik, "HugMe: An interpersonal haptic communication system," in *2008 IEEE International Workshop on Haptic Audio visual Environments and Games*, 2008: IEEE, pp. 99-102, doi: 10.1109/have.2008.4685306
- [43] S. Demain, C. D. Metcalf, G. V. Merrett, D. Zheng, and S. Cunningham, "A narrative review on haptic devices: relating the physiology and psychophysical properties of the hand to devices for rehabilitation in central nervous system disorders," *Disability and Rehabilitation: Assistive Technology*, vol. 8, no. 3, pp. 181-189, 2013, doi: 10.3109/17483107.2012.697532
- [44] M. Awais, F. Ullah Khan, M. Zafar, M. Mudassar, M. Zaigham Zaheer, and K. Mehmood Cheema, "Towards enabling haptic communications over 6g: Issues and challenges," *Electronics*, vol. 12, no. 13, p. 2955, 2023, doi: 10.3390/electronics12132955
- [45] S. Palaniappan, R. Logeswaran, and Y. L. Yong, "Machine Learning Model for Assessing Human Well-being Using Brain Wave Activities," *Journal of Informatics and Web Engineering*, vol. 4, no. 2, pp. 93-113, 2025, doi: 10.33093/jiwe.2025.4.2.7.
- [46] S. Giri, M. Kandasamy, and M. Rafaliya, "The Impact of Deep Learning in Brain Tumour Analysis," *Journal of Informatics and Web Engineering*, vol. 4, no. 2, pp. 236-247, 2025, doi: 10.33093/jiwe.2025.4.2.15.
- [47] Bailey, R.P., Hoe, T.W., Morrison, G.Z., Ali, A. and Samsudin, N., 2026. Rethinking higher education: embodied learning and pedagogical transformation. *Higher Education*, pp.1-21. <https://doi.org/10.1007/s10734-025-01581-2>.
- [48] Sirwal, S.A., Ahmad, B. and Koul, M.H., 2026. Haptic guidance: Advancements, challenges, and future directions in human-computer interaction. *Proceedings of the Institution of Mechanical Engineers, Part C:*

Journal of Mechanical Engineering Science, 240(9), pp.3136-3164.
<https://doi.org/10.1177/09544062261416177>.

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