REPLY

OVERVIEW OF HAPTIC INPUT FOR VIRTUAL REALITY AND SPATIAL COMPUTING

Reply carried out an overview of the main haptic products on the market, developing comparisons between different gloves, suits and VR devices that enable totally immersive experiences, reaching extremely high levels of realism within Virtual Reality.

REPLY specialises in the design and implementation of solutions based on new communication channels and digital media. As a network of highly specialised companies, Reply defines and develops business models enabled by the new models of AI, big data, cloud computing, digital media and the internet of things. Reply delivers consulting, system integration and digital services to organisations across the telecom and media; industry and services; banking and insurance; and public sectors.

www.reply.com

INTRODUCTION

The researcher William R. Sherman identifies four fundamental properties which are necessary to talk about a virtual reality (VR) environment.

Immersion, the property that describes the perception of the virtual world as real, in order to obtain an estrangement from the real context.

Presence, the property that describes the feeling of belonging to the virtual world. The viewer voluntarily suspends the critical faculties to mentally immerse himself in the virtual world.

Interactivity, the property that consists in increasing user involvement by allowing him to interface with the virtual environment. The devices of interaction can be classified according to degrees of freedom, technology used and the characteristics of the data exchanged.

Predisposition to imagination, the property that allows the viewer to overcome the limitations imposed by the approximation of characteristics real in virtual ones. It can be assumed that improving these properties by importing haptic technologies as an output interface in a VR system and increasing the number of sensory channels lead to an improvement in the immersion and realism of the virtual experience.

For example, the authors of the article "Validation and learning in the Procedicus KSA virtual reality surgical simulator" describe the research carried out at the Karolinska Institutet at Huddinge University Hospital, where fifteen students underwent an endoscopic virtual training simulation. The students were evaluated before and after an hour of training using two endoscopic simulators. One differed from the other because it was equipped with an anatomical graphic display and a tactile sensor, able to provide haptic feedback in the event that an organ is touched.

The simulators measured performance and provided a quantitative result at the end of each task in terms of time spent, number of movements performed and overall score.

Improvement in total scores in the first simulator was expressed as negative values in contrast to the haptic feedback simulator, where an improvement was measured in positive values.

As expected, the learning curves analyzed show that the results of research on the use of surgical simulators as a training tool were encouraging. In fact, the authors of the article suggested the integration of surgical simulators within the surgery courses before the development of negative stereotypes and incorrect practices.

The integration of haptic technologies with more traditional surgical virtual simulators offers the possibility to work in less expensive, safer environments and to benefit from less steep learning curves. Healthcare and training are just a few examples of how a higher level of immersion thanks to haptic feedback provides better experiences with extended memorization.

SOLUTIONS

In this section we provide an overview of the **most important market solutions** of haptics products, according to available data as of January 2022.

ULTRALEAP

TESLASUIT

WEART

HAPTX

MANUS VR
PRIME X HAPTIC VR

VR GLUV

SENSE GLOVE
NOVA

ULTRALEAP

Ultraleap was formed when Leap Motion and Ultrahaptics came together in 2019. They have created an **advanced hand tracking** with the only haptic technology that creates the sensation of touch in mid-air.

The first solution from Ultraleap replicates haptics sensations through the use of particular boards. Each board is composed of an array of ultrasound speakers, which emits ultrasound waves, which have a frequency so high that it is not possible for the human ear to hear. Every ultrasound speaker in the array can be individually controlled. Ultraleap developed some algorithms that allow it to coordinate all the speakers, triggering them with some time differences in order to make the waves arrive at the same time in the same point, called focal point.

They use a Leap Motion hand tracking device (that uses two cameras and some infrared LED) to track the position of your hand and to position the focal point at a spot on it.

The combined ultrasound waves have enough force to create a tiny dent that can be detected from the touch sensors of the hand skin.
This device has different functions, like reproducing virtual buttons, sliders and haptic pulses.
It also allows you to recognize textures and virtual objects, with different shapes and surfaces.
Ultraleap used that and developed two different commercial solutions:

- **STRATOS Explore**, built for research and development, whose applications are automotive, appliances/smart home, kiosks, gaming and computing applications.
- **STRATOS Inspire**, a robust plug-and-play haptic module suitable for creating sophisticated mid-air tactile effects for experiential marketing, digital out-of-home installations and location-based entertainment.

Ultraleap provides a system development kit for some game engines and a demo environment for the developers who want to design and create new experiences.
In October 2021 the IllusiOcean exhibition took place at the Bicocca University of Milan, where the wonders of the sea were shown to the public through the language of illusions. In this regard, Infinity Reply collaborated with the MIBTEC (Mind and Behavior Technological Center) to produce a sensory experience through a STRATOS Explore device.

The application was a simulation of the underwater geysers and the reproduction of the tactile sensations resulting from the bursting of the bubbles with the hands.

The development of the application consisted in the integration of the graphic assets, a particle system to manage bubbles and the assets provided from the SDK. In particular, the Ultra Leap and Motion Leap Unity plugins allow users to easily manage haptic feedback and the collisions of the tracked hands with virtual objects.

TESLASUIT

Teslasuit is an HMI design in the form of a full-body XR suit. Teslasuit is compatible with many game engines and has an open API and SDK to allow for integration into simulated environments. Three integrated systems include haptics, motion capture and biometry to provide a realistic immersion:

• **Haptic feedback system**: it is built into the suit and can be engaged on actions, on demand or in response to motion capture comparison. The feedback is delivered via Electronic Muscle Stimulation (EMS) and Transcutaneous Electrical Nerve Stimulation (TENS) using dry electrodes.

• **Motion Capture system**: it consists of 10 inertial sensors and sophisticated drift reduction algorithms to accurately transfer movements from the real to the virtual world.

• **Biometry system**: it allows to collect real time data from users while training which can be used to relay emotional state, stress level and key health indicators.

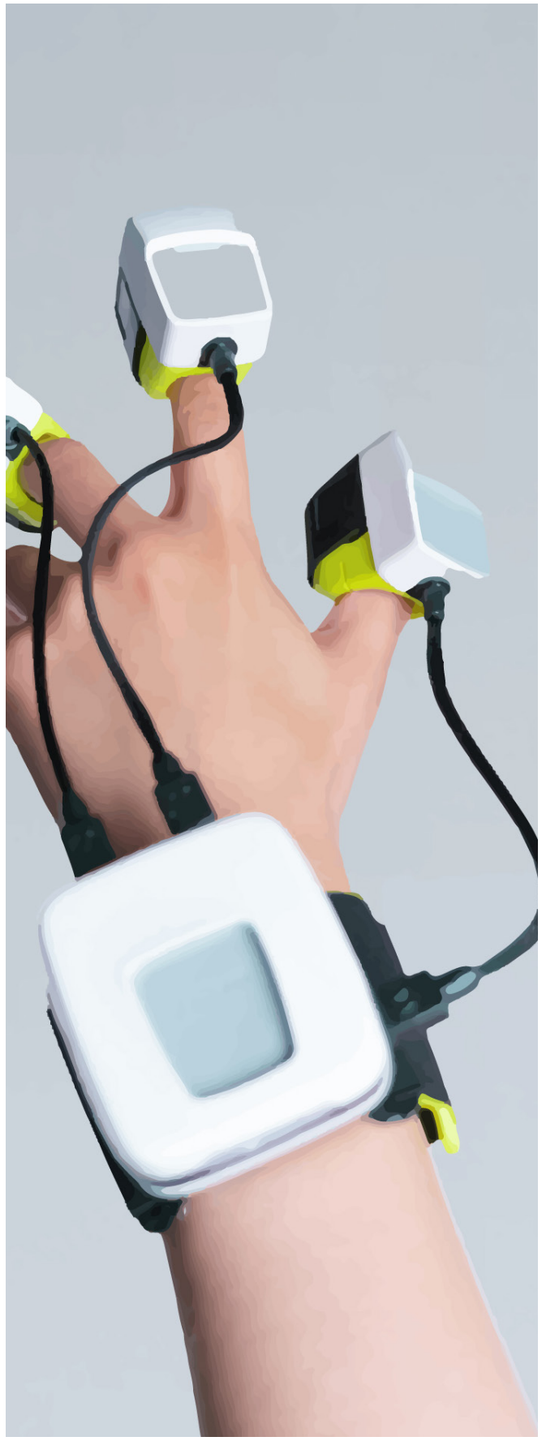
As technologists, we are constantly researching and experimenting to develop new solutions and we have considered Teslasuit one of the most sophisticated solutions for a high level of immersion with full body haptic feedback. Reply is currently exploring this device in the AREA360 and is working to integrate Teslasuit into various VR training applications.

Before using the haptic feedback feature of the suit, it is necessary to perform a haptic calibration for each user. This is because each individual perceives the feedback in a different way and values that are not perceptible to someone can be annoying for someone else.

Teslasuit provides their launcher where it is possible to do the calibration. During one of the first uses of the suit, we forgot to calibrate the power of a pair of electrodes. As soon as one of us grabbed a fireball in the simulation, the feedback was so high that their hand opened, realising the controller and dropping the fireball on the ground where it exploded. At the end of the explosion effect, the person was on the ground and, in that moment, we realised we missed some values. However, we immediately learned that it is better to first carry out a calibration in “area mode” and then move on to calibrate specific areas so it is easier not to leave out anything. Further research is ongoing and we are actively improving the experience every day and we already managed to get nice haptic feedback with the correct calibration and settings.

Teslasuit Gloves integrate different technologies in order to enhance immersion while collecting as much user data as possible. In particular, the surfaces at the level of the fingers are able to reproduce certain tactile sensations. In addition, the glove has a force feedback function for each finger. On the motion capture front, the gloves accurately measure the position of each finger and the rotation angle of the wrist, as well as the position of the glove in space. Finally, the thumbs are equipped with both a pulse oximeter to measure oxygen saturation in the blood and an impedance measurement system to measure the user’s heart rate and “emotional state”. Teslasuit Gloves connect to the suit via Wi-Fi to provide an almost total capture of the user’s body movements.

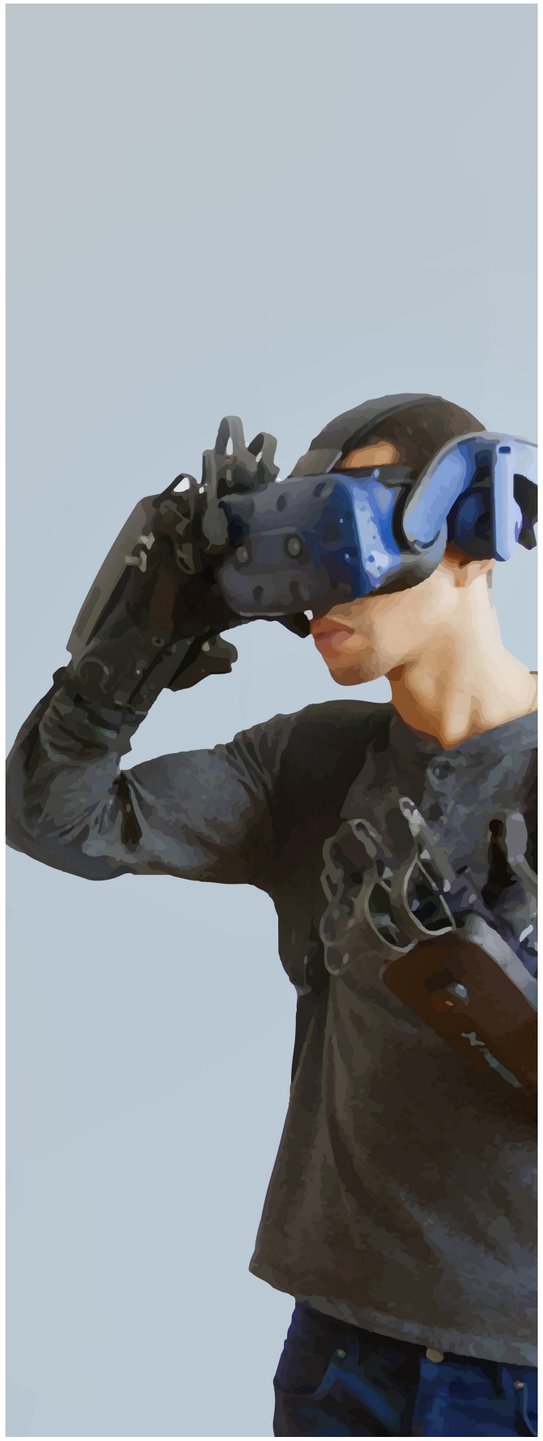
The Teslasuit Gloves are currently under development and we will explore those in combination with the Teslasuit itself once the gloves become commercially available.



WEART

The WeArt product combines forces, vibrations and thermal cues to achieve a high level of realism in the VR experience. Their complete configuration includes three actuated thimbles, with three different size adapters, that stimulate the user's hand, for a compelling haptic rendering.

From a Control Unit it is possible, at any time, to unplug each thimble if it is needed. Tracking of the user's fingers is achieved through an innovative technology integrated in the device coupled with a digital model of the human hand, that is included in the SDK. The **TouchDIVER** comes with a Universal Adapter hosted on the Control Unit that can be used to plug-in most commercially available controllers (HTC Vive Trackers, Oculus Controllers etc.). Additionally, it is possible to sample the haptic textures of custom surfaces with a special WeArt device that provides the sampled surface texture data back into the TouchDIVER. This way custom garments and other textures can be integrated into a VR experience. Reply acquired a set of the WeArt devices and it's currently exploring options for enhancing a VR training case. The goal is to reach an even higher level of immersion grabbing virtual objects, also with thermal feedback.



HAPTX

HaptX Gloves DK2 provides realistic touch sensation using pressure. Built with patented microfluidic technology, they offer high accuracy for professional applications.

Haptx gloves displace the user's skin like a real object would. **Microfluidic tactile actuators** cover the full palm and fingertips. Exo Tendons dynamically apply up to 40 lbs. (175 N) of resistive force per hand. Custom-designed magnetic mocap tracks 30 degrees of freedom (DoF) with sub-millimeter precision.

Multiple pairs of HaptX Gloves can be **networked together** for collaborative haptic VR experiences. The kit is composed of HaptX Gloves, an air controller, a smart compressor and a software development kit.

MANUS VR PRIME X HAPTIC VR

Manus VR produces a range of motion tracking gloves and also one with haptic feedback. The Prime X Haptic VR gloves provide **powerful feedback on each individual finger**. With the improved haptic modules, the Prime X Haptic VR gloves provide a sense of touch with a high resolution but just simple force feedback.

The Manus gloves calibration process is composed with just simple gestures. The gloves come equipped with interchangeable batteries, with battery life of about 5 hours of continuous use of the device. Gloves instantly reconnect after swapping the battery, eliminating recalibration downtime.

The gloves are washable, after removal of some sensors from the glove textile. There is the possibility to acquire additional glove textiles separately so all team members have their own personal set, simply swap the sensors from one textile to another to use the same hardware. The biggest downside of the Manus VR Prime X Haptic VR gloves is the simple force feedback mechanism that stands behind more sophisticated solutions.

VR GLUV

VR Gluv Enterprise Haptic Gloves make use of a patented Force Feedback technology and a lot of new features to give you full control of your hands in VR, unlocking a wide variety of new interactions, experiences and gestures. The **active Force Feedback** is of approximately 40 Newtons and is applied on each finger to simulate the size, shape, stiffness and impact of any virtual object. There are also some integrated force sensors used to measure fingers' resistance and allow them to manipulate hard and soft objects with human-like touch. VRgluv's hand and finger tracking technology provides an **accurate and reliable motion capture experience**, calibrating to the user's hands in less than 30 seconds.

Each finger features 3 degrees of freedom tracking including finger splay and individual joint motion capture. Low-latency Bluetooth wireless sends and receives both hand tracking and haptic data. Swappable batteries allow you to remain in VR for extended periods of time without having to take off your gloves.
VRgluv is compatible with all most important headsets like Oculus, Vive, Valve Index. Some ideas of applications are related to medical military training and in the driving simulation of an F35.

SENSE GLOVE NOVA

SenseGlove Nova is the last solution of haptics devices explored. Using these gloves, the VR object can feel real thanks to the force-feedback system that puts out 20 Newtons of resistance within 10 ms.

SenseGlove has embedded an **advanced voice coil actuator technology** that allows the Nova to render the feeling of realistic button clicks and impact simulations. Thanks to all these properties, SenseGlove Nova can be used for VR training, composed of tools and dashboards.

SenseGlove Nova combines sensor-based finger tracking with computer vision hand tracking algorithms. The SenseGlove Nova is quite often seen used in conjunction with the Pico Neo 2 headset, that can automatically track the gloves. SenseGlove Nova can be used with Oculus Quest and HTC Vive headsets by mounting the controllers on the gloves.

COMPARISON

Reply experts explored all of the mentioned solutions by looking at their **technical specifications**, **reviews** and **custom experiments**. Then the main attributes of the tactile device were compared between the different vendors and a comparison matrix of the available solutions has been created, simplifying the choice of the right device.

DEVICE VENDOR	TYPE	FORCE FEEDBACK	MOTION TRACKING	THERMO-FEEDBACK	TEXTURE RECOGNITION	SDK
Ultraleap	Ultrasound board	yes	yes	no	yes	C++/C# API, Unity plugin
Teslasuit	Suit	yes	yes	yes (only suit)	yes	Unity, Unreal plugins
WeArt	Finger sensors	yes	yes	yes	yes	Unity, Unreal plugins
HaptX	Gloves	yes	yes	no	yes	C++ API, Unity, Unreal, Steam VR plugin
Manus VR Prime X Haptic VR	Gloves	yes	yes	no	yes	C++ API, Unity, Unreal, Motionbuilder plugin
VR Gluv	Gloves	yes	yes	no	yes	Unity, Unreal, Steam VR plugin
SenseGlove Nova	Gloves	yes	yes	no	yes	C++, C# API, Unity, Unreal plugin

CONCLUSION

Haptic feedback provides a **higher level of immersion** and **realism** for Virtual Reality experiences.

The market of vendors is growing constantly and we selected the major players in the field where we see the most promising results. The market and devices are still in their infancy and have downsides with bulky equipment, lengthy custom calibration, limited battery life and challenging hygienic practices for shared scenarios.

Reply is currently exploring further use cases and is conducting research to improve existing solutions with our clients for better immersive experiences and to overcome some of the challenges.

REACH NEW PEAKS OF REALISM WITHIN A VIRTUAL REALITY SCENARIO THANKS TO REPLY'S EXPERTISE IN INNOVATIVE HAPTIC PRODUCTS