# User Interface and User Experience for Virtual Reality Using Biopotential: A Virtual Reality System with Cross Platform and Plug-and-Play Capability

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**Abstract:- The developing virtual reality and augmented reality platforms broaden the need for a more intuitive form of Human-Computer Interaction. Although many devices implement a virtual reality into their design, it focuses mostly on visuals and audible environment, the touch sensory haptic is a very significant factor that determines the physical interaction between the virtual environment and the user which for the most part is overlooked or very crudely implemented. Most of the haptic devices currently available are made for working with specific programs or require an adaptation to perform with various tools and applications. This limits the multiplatform usage and also hinders plug-and-play functionality. By simplifying the data stream from such virtual devices, this haptic arm focuses on an interface for virtual reality devices that can be applied as a Human Interface Device for pluggable-USB communications, making way for a much cheaper and multiplatform capable virtual reality haptic devices (i.e. VR gloves, Haptic gloves, Motion capture suits etc.) and one-to-one animatronic (i.e. Exoskeleton, robotics, control panel etc.) without use of expensive digital sensors or graphics intensive platforms. The advent of virtual reality and 3D graphics simulation paved the way for a more intuitive Human-Computer Interface that bridges the gap between humans and machines. Furthermore providing a realistic experience of human interaction in the form of vision, sound and touch.**

***Keywords*:-** *Exoskeleton-Arm; Haptic-Arm; Virual Reality-Arm*

## I. INTRODUCTION

The currently used haptic glove or data glove in virtual reality applications have a specific set of data recorded or sensed from the human hand to be processed by the ad-hoc program designed to analyze and track the hand motion in space. Using this information, the program can then decide the graphics processing and also the necessary feedback to be sent back to the device. The haptic feedback usually being vibration motors and actuators, can give a sense of physical parameter to the virtual environment for the user. Although the feedback can be accurate and precise, it becomes dependent on input electrical power as the feedback intensity is raised, also adding to the mechanical system that can be bulky. There is very much a need for mechanical hardware so as to translate the virtual parameters as a force and touch feedback. The limitations of a haptic glove will be its physical structure and the energy required to run such devices. To maximize efficiency with ease of use, IMU sensors are used most commonly used to track motions for more accurate implementation of hand motion tracking and capture. Unfortunately, IMU sensors are much expensive than passive sensors and are very sensitive to even slight motions. A filter algorithm must be used to reduce noise and provide a one to one motion scaling (displacement in the virtual environment must match displacement in reality). All in all, making the computation of such devices to be defined by the manufacturer and calibrated to match the required functionality, thus the use of ad-hoc programs are needed to fully handle the device, resulting in limitations such as cross-platform usage and preferable specific system requirements to handle the data stream and process that data. A device of such complexity can make it hard to calibrate and actuate for various applications and usage. In this design, a basic protocol for a common parameter of sensory data and haptic feedback control is built in such a way to imitate HID interfaces used to pair peripherals such as a mouse, keyboard and joystick. With a simple user interface and cross-platform functionality of HID based interaction, virtual reality devices can be easily manipulated and used as a pluggable USB device like a mouse, keyboard etc. To make computations even easier and intuitive, the hand motion must be tracked into individual axis for the specific joints in the arm. Instead of using IMU or flex sensors, the Exoskeleton-arm uses daisy chain links to calculate the position of individual joints of the human arm and feedback parameters, allowing ease of post-processing and manipulation later in the computer GUI.

## II. HUMAN INTERACTIONS

*A. Purpose*

The interaction of a human with any computer or technology is made more productive and less abstract when the full sensory of vision, audio and touch are felt. This can be observed in the use of touch screen compared to the use of a mouse or keyboard. The visual aesthetic of touching an element on the screen is much more productive and effective in usage, rather than to use keyboard strokes or mouse movement. By combining all the three essential elements of interaction, one can experience transfer the experience of the real world physics into a virtual environment that is entirely abstract in a computer but made physical using this technology.

*B. Scope*

The Human-Computer Interface is a much necessary feature for any technology or device that actively needs the human to interact within a multidimensional field. This haptic arm intends to make the wearable virtual reality suit to be easily adaptable to any sort of environment by providing a much flexible user interface with data from each joint in the human arm and also a controllable feedback system to provide a parameter from the environment to actuate physical forces. The scope of such a device gives a new dimension for the use in virtual reality, augmented reality, graphics simulation, gaming, user interfacing, 3D modeling, medical instruments, rehabilitation exoskeleton etc.

## III. SENSING MOTION

Sensing motion is the most important factor that determines the number of sensors and how that data is calculated. By implementing passive sensors, the cost of the whole device can be greatly reduced.

The various sensors that can be used for motion tracking feature a multi-axis such as x, y, z-axis degrees of freedom. These sensors are digital and need to be processed by a microcontroller to retrieve the data. Using multiple digital sensors is expensive and also needs a large data transmission rate between the device and the processor. This can also lose energy efficiency for a battery-powered device. Thus a digital sensor is not an option for this haptic arm, instead, passive sensors are used to make the device collect more data and be energy efficient and also be easy to service as modules. To make the exoskeleton-arm more robust and sleek without much mechanical bulk, the sensors are manufactured as thin film membranes.

## IV. SENSORS

There are many ways to track motion, in which case the generally used IMU sensor is not effective and cost efficient for multiple point tracking. Thus in this case with the aid of an Exoskeleton-arm, we use the following components for tracking motion.

*A. Thin-Film Variable Potentiometer*

The sensing element of each joint is made as a plastic membrane that works much like a slider potentiometer but with only two thin sheets of the carbon layer and an electrically conductive sheet sliding between the two layers. The setup is attached over the joints such that bending of the fingers or arm causes the layers to displace within. This enables us to register the movement of a joint as a change in value ohm's across the thin-film potentiometer. This reduces the need for any mechanical aspect for the sensor and can be layered with the structure of the exoskeleton-arm.

*B. Rotary Encoders*

Another useful sensing method is by using rotary encoders or absolute encoders based on the nature of the joint movement. For joint movements that cannot be sensed using thin-film potentiometer, a rotary encoder enables the use of gears and complete cycles of rotations, which can be useful in terms of magnifying a joint motion by use of gears and or pulleys.

*C. Force Sensors*

The force sensor is a parameter control element that determines the range of exerted force on the human arm and acts as a feedback control loop for the microcontroller to know if the desired force is reached or not.

*D. IMU Sensors*

In the case where the position of the user is needed, a single or few IMU sensors can be used as a point of reference for the rest of the sensors on the exoskeleton-arm. The IMU sensor can be used for positioning the user in relation to the rest of the sensor data that are linked in a daisy chain network.

*E. Electromyography Sensor*

In purpose for analyzing amputated limbs, the EMG sensors are implemented to sense the electrical signals sent to the muscles from the brain. This helps in rehabilitation and analyzing how the brain interacts with the amputated limb.

## V. SENSING METHODS

The virtual reality implies the interaction of the human body with the virtual world; this mainly focuses on the hand and how it interacts with the physical geometry of the virtual environment as shown in the Figure 1.

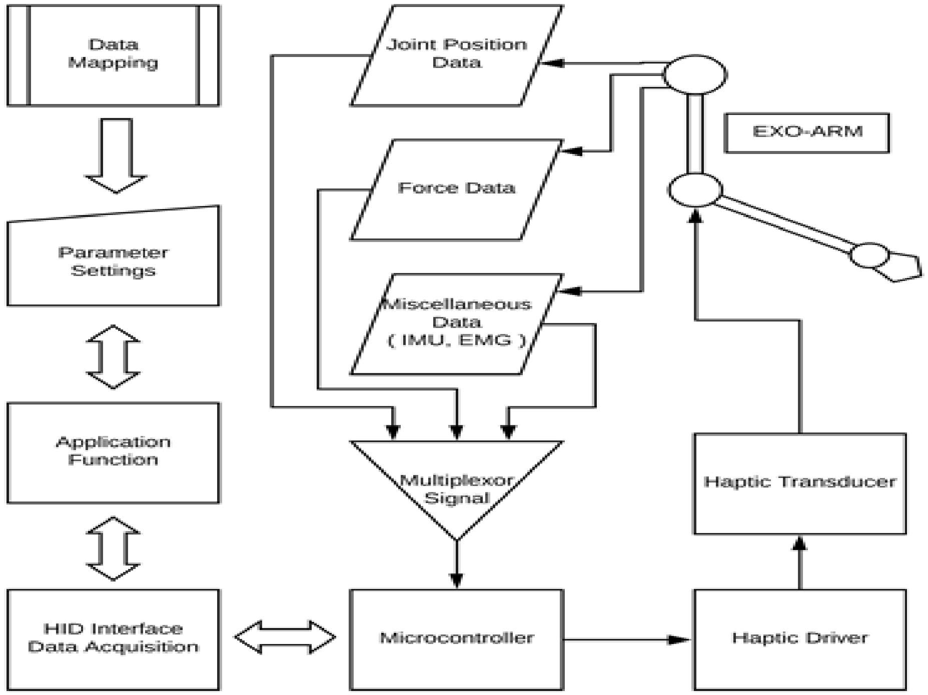

Fig 1:- Control Flow of Exoskeleton-arm

*A. Hand Motion Sensing*

Hand motion tracking can be sectioned into two types, individual finger movement and position of the whole hand. To compute the position of the hand in space, an external imaging method, ultrasonic scanning or Internal sensors in the device are the most commonly used types of motion sensing for low-level virtual reality data gloves. Some high-end motion tracking uses image processing or IR camera motion tracking etc. In the above methods, most of the sensing methods are digital sensors, preferably for ease of application and 3d motion sensing. Though this can seem effective, it restricts the level motion tracking of individual joints in the arm. With one sensor computing position in degrees of freedom of multiple axes and also presumably the movement of the individual fingers, it reduces the need for more sensors in its place. This also greatly reduces the flexibility of individual control of the joints. Instead of tracking the motion of the sensor in space or using image processing, we use individual passive sensors placed at every joint of the arm, giving us full control of the data from the glove.

*B. Sensors Network Connection*

The multiple sensors used in these exoskeleton-arm results in an abstract data set with no actual interrelationship between the sensors. By implementing a daisy chain algorithm to link each sensor to relate to both the previous and next sensor, this helps us to manipulate the virtual environment with relation to the individual axis from the glove. We used approximately 32 various inputs from the glove. This is continuously sent to the HID interface for controlling and mapping the address of the axis to the application that's using this virtual reality protocol. With the addition to the movement of joints, we also sense the force and capacitive touch of the fingertips so that the haptic feedback can use this data to trigger the actuator.

## VI. CONTROL SYSTEM

The control system is the electronic processing of the various inputs and outputs that are determined by the virtual environment and the parameters set by the user.

*A. Internal Microcontroller Unit*

Although the device used in such a virtual reality platform is known to use high-end processors for data acquisition, this Exoskeleton-arm is designed to use any microcontroller that can handle multiple GPIO. It is recommended that the MCU has a fairly high processing speed since the number of data lines to be processed is large and is directly proportional to the resolution of the data collected from the exoskeleton-arm.

*B. Multiplexor*

Since there are only a few limited analogue GPIO ports in any standard MCU, we use a multiplexer to give more control over the number of analogue input channels that are necessary. The multiplexer is a very important part of the processing because it helps simplify the multiple data stream into a single array of data set, which is easy for data acquisition and transmission compared to single channel data transmission.

*C. Excitational Feedback*

Related to haptic feedback, this data consists of the basic trigger signal to which the haptic drivers must react. This signal is an external interrupt given to the MCU from a computer or other feedback system. This signal is designed to tell which output feedback driver must be activated and what is the parameter that has to be reached. This can be positional feedback or force feedback, depending on the parameters set by the computer or external feedback system such as robotics.

*D. Data Acquisition*

From the data of the various joints in the hand, we now have to map these data to a target host, which can be a computer application, simulation, game, robotics or instruments. This is fairly simple as the device is intended to be HID compatible USB, such as a mouse, keyboard or joystick. This removes the need for a graphics processor to work separately to process the exoskeleton-arm data. This also means that the device is compatible with all major operating system regardless of its processor specification. The data can be used to control the actuation of external devices such as motors in robots.

## VII. HAPTIC SYSTEM

The haptic system is the tactile feedback and force feedback that enables the experience of geometry and surface contact that is made in the virtual world. It combines mechanical system and electrical transducers that imitate tactile and force feedback in real life.

*A. Haptic Feedback*

Haptic feedback can be simplified into two types, tactile sensation and forced feedback sensation. Tactile sensation also includes touch sensation of texture and thermal conductivity, and also the immediate restriction of movement caused by physical interaction. Forced feedback is the implied force exerted by an external object such as experienced in carrying the weight of an object. To understand these two types of haptic feedback, the tactile sensation is analogous to touching a textured object such as a metal ball. Forced feedback is the force applied on a body such as experienced when dribbling a basketball, the force exerted when the ball hits the hand. With these two types of haptic, the implementation of actuators to apply necessary force on the user's hand is possible with the use of the HID interface. The mechanical aspect of the arm is designed to work passively and triggered by solenoids.

*B. Haptic Drivers For Tactile and Force Feedback*

The haptic driver sends out PWM signal from the MCU that enables accurate control of the solenoids that are used as the transducer for the haptic feedback. The transducer has a tightly wound coil that actuates an armature with opposing magnets on each end. This enables a linear position actuation, which is used for force feedback and touch actuation. The surface that comes in immediate contact with the human arm will be enabled with a force sensor, which is a parameter control for regulating the force acting on the body. This completes the control flow loop of an exoskeleton-arm that receives inputs from the hand movement and transmits it to the host, which returns feedback that actuates the haptic transducer.

## VIII. PERFORMANCE

The performance of the device is determined by initial calibration of the sensors and the host system. This alignment is crucial for a one-to-one replication of hand movement. The haptic feedback is actuated completely by the host computer or robotic which sets the parameter for actuation. This has to be aligned to meet the desired effect of touch. The intention of the haptic arm is to make the device work with passive sensors and have no need for a graphics processing of the data. This greatly reduces the processing power needed to operate such devices.

## IX. DISCUSSION

The choice of passive sensors is debatable to how accurate and sensitive it can be to a motion, but it is to be kept in mind that the design intends to reduce production cost and also make it compatible with almost all-processing system. Implementing dedicated thin-film sensors for the joints increases accuracy and sensitivity. The daisy chain method of the sensor network is used to eliminate the need for digital sensors; it is required for the whole arm to be sensed in order for this to work. The haptic transducers are relative to the power supplied to the drivers, more power is translated to more powerful force feedback. The HID-compliant connection is not necessarily a graphics device, but it can provide an application with all the necessary data to manipulate any 3D intensive program. Though this is an indirect interaction, it eliminates the need for the 3-dimensional tracking of the arm and finger. The device is intended for ease of service and repair, as the parts used are very cheap and readily available or easy to manufacture.

## X. CONCLUSION

The importance of a Human-Computer Interface is growing more necessary than just a feature with the advent of virtual reality and augmented reality environment. The devices that enable hand controlled interfaces make the peripheral more ad-hoc to specific functions rather than a universally adaptive device that can be used with any platform of operation. This opens a new dimension into 3D interfacing that can finally enable the user to not just see and hear but also to feel a virtual object.

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