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Novel Approach for Surface Simulation - Virtual Reality

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Abstract: Haptics is one of the most trending technologies in the world as per the famous GARTNER 2014-15 predictions. This makes it one of the leading technologies to be focused on in the field Engineering and Research studies and robotic applications. It Deals with the simulation of real-world experience using concepts such as augmented reality, virtual reality and mixed reality. This technology provides the user a force, sense and touch feedback. The proposed work aims at perceiving and simulating different surfaces or textures and further providing real-time experience of virtual objects or surfaces allowing the blind users to visualize and sense their surroundings much like bats or dolphins. The proposed work involves building of two devices namely Hand module and Puck scanner, one measures the response of surface with respect to the human interaction, different amount of pressures are applied and wide ranging responses are obtained which are stored in the database and later produces the virtual feel of the same using object recognition involving feature extraction and feature matching process, the module is programmed such that typical frequencies are generated for different pixel values of the matched image and thus giving different vibrations through actuators creating virtual effect of the captured surface.

Keywords: FSR, Augmented reality, Haptics, Feature extraction, Virtual reality.

I. INTRODUCTION

Haptics technology mainly deals with computer interface devices. It promises to bring profound changes to the way humans interact with information and Communicative ideas. Recent development in computer interface technology now permits us to touch and manipulate imaginary computer generated objects in a way that evokes a compelling sense of tactile realness. Haptics interactions might be as simple as touching a virtual wall or button, or as complex as performing a critical procedure in a surgical simulator. Haptics is the science of applying tactile, kinesthetic, or both sensations to human Computer interactions. It refers to the ability of sensing and/or manipulating objects in a natural or synthetic environment using a Haptic interface.

Haptics is most widely used in virtual Reality applications wherein haptic controllers give the ability to create force-torque like feedback in a device that is more compelling than vibration feedback, but simpler and less expensive. In medical field, haptic simulation technologies brings tactile realism to medical education, creating an engaging multisensory experience that helps increase clinical proficiency and decrease medical errors and cost. Haptics also finds extensive applications in Mobile touch screen devices, virtual keyboards and in gaming to provide enhanced realistic feel to the users.

Haptics technology in the field of computer interface devices brings out the profound changes to the way humans interact with information and communicate ideas which allows us to touch and manipulate imaginary computer generated objects in a way that evokes a compelling sense of tactile realness. Haptics technology provides force feedback to users about the physical properties and movements of virtual objects represented by a computer by specialized hardware.

There are some important elements of haptics which all together provide a complete force feedback to the user. They are briefed in the below section.

Haptic perception is the process of recognizing objects through touch. It involves a combination of somatosensory perception of patterns on the skin surface (e.g., edges, curvature, and texture) and proprioception of hand position and conformation (author et.al[1]).Haptic perception relies on the forces experienced during touch. Haptics display is a mechanical device configured to convey kinesthetic cues to a human operator. Haptic displays vary greatly in kinematic structure, workspace, and force output. Haptic rendering is defined as the process of computing and generating forces in response to user interactions with virtual objects. Haptic interface is a system that consists of a haptic device and software-based computer control mechanisms.

Haptics technology uses sensors, haptics actuators and driver circuits for driving actuators. Tactile sensor is a device that measures parameters of a contact interaction between the device and some physical stimuli. Tactile sensors are found to be best suitable for haptic applications as they have a high-density and narrow covering area. Four types of actuators are used in haptic systems and each has specific functionality and performance characteristics that will influence its suitability for a particular product. These include Eccentric Rotating Mass (ERM) Actuators, Linear Resonant Actuators (LRAs), Piezo Modules, Electro-Active Polymer Actuators (EAPs).(author et.al [2]) From the various sensors available to perceive surface information from different surfaces, Force Resistive Sensor (FSR) was found to be most suitable for our application. These sensors provide

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resistance change as output for the applied force or pressure. The behavior of the FSR sensors is such that the resistance varies inversely with the applied pressure.

For the purpose of actuation, Eccentric rotation mass (ERM) actuators were found to be feasible for our application because of its low power consumption, ease of use and robustness of the device as compared to LRA and Piezoelectric actuators. The behavior of ERM actuators is such that the frequency of actuation increases with the input voltage. (Author et.al [3])

II. RELATED WORK

Some of the relevant literary works in this field are explained briefly below these work give an idea about the haptics .The studies related to simulation, mathematical modeling of existing devices, human interaction with the devices and its evaluation, study of surface variability and its effects on haptics feedback and physical Design and modeling of the devices are discussed below:

A system that provides combined auditory and haptic sensations that arise while walking on different grounds was described by Luca Turchet et.al [4]. The simulation was based on a physical model that drives both haptic transducers embedded in sandals and headphones. The model is able to represent walking interactions with solid surfaces that can creak, be covered with crumpling material. The simulation responds to pressure on the floor by a vibrotactile signal felt by the feet.

After the study of surface simulations and feedback from the surface, in order to evaluate the role of vibrotactile feedback in enhancing the realism of walking experiences in multimodal virtual environments several experiments were described by Rolf Nordahl et.al[5]. Evaluation was performed by employing an interactive and a non-interactive multimodal feedback system. In both the configurations subjects were exposed to auditory and audio-visual stimuli presented with and without the haptic feedback. Results of the experiments provide a clear preference towards the simulations enhanced with haptic feedback showing that the haptic channel can lead to more realistic experiences in both interactive and non-interactive configurations

Further, the analysis and construction of virtual Haptic surfaces from a perceptual point of view was presented by Louis B. Rosenberg et.al[6] .Perceptual decomposition of surface contact sensation was developed by examining three qualities associated with the different stages of interaction with haptic wall simulation. These qualities are the crispness of initial contact, the hardness of surface rigidity, and the cleanness of final release from the virtual wall's surface. These qualities and an overall rating of wall quality were employed consistently by seven subjects to evaluate a set of six simple haptic wall simulations.

Correlations showed that, according to subjective rankings from these experiments, fundamental qualities Initial contact(IC), Surface Rigidity (SR), and Final release (FR) were dependent on each other. Also, partial correlations showed that the overall rankings (OW) were strongly related to subject perception of surface rigidity (SR) and final release (FR), but not with initial contact (IC) quality of the haptic wall models.

A novel approach to assist blind people during navigation between waypoints (walk straight) with actors on their wrists was proposed by Slim Kammoun et.al [7]. The main goal is to decrease the cognitive load needed by blind people to follow instructions in overloaded environments. Two issues were discussed, they were

- The number of vibration motors used and
- The type of vibration dimensions issued.

The design enabled the users to easily set up and use the haptic system to receive feedback on their route. The actuators enable us to control the frequency, duration and interval between stimuli.

These are the few related works in this field with respect to the type of sensors to sense the surface variability, type of actuators to provide vibro-tactile feedback to the user, driver circuit to drive the actuators and the mathematical modeling for the various random input data from the user were also studied.

III.PROPOSED ALGORITHM

Based on the literature survey, in order to provide virtuality it is necessary to develop the project in two phases. First phase involves extraction of the features such as vibration and reaction from different surfaces or textures and the second phase involves matching the features with those in the lookup table. The block diagram implementation of entire project is as depicted in Fig1.

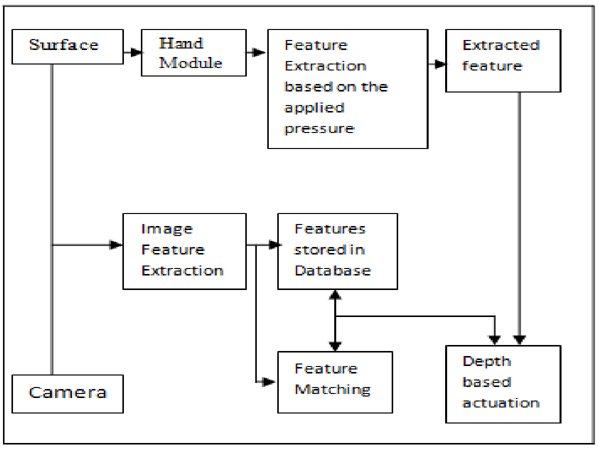

Figure 1: Block Diagram for Haptic Simulation.

As shown in the above block diagram, the surface block represents the wooden surface with constrictions used in the project. The wooden surface is as shown in fig 2. (Allison et.al [8])

Further, a Hand module is developed to acquire reaction of different surfaces to the applied pressure. In the designed module the sensors are placed based on the studies made on pressure points of the hand.

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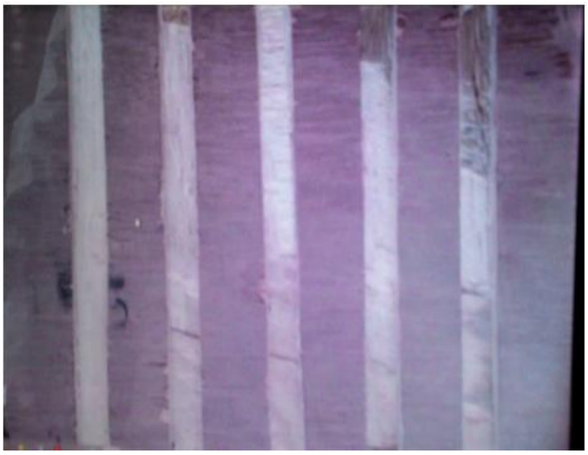

Fig 2: wooden surface with constrictions under study.

The sensor position on the module of hand which is in contact with the surface is as shown in Fig 3.

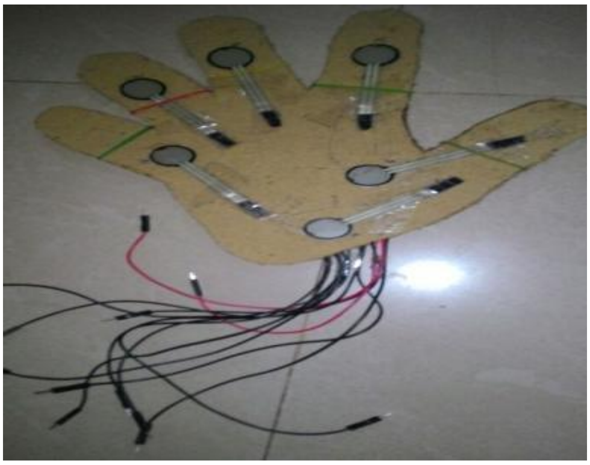

Fig 3: Module of Hand with FSR Sensors.

The hand module is mathematically modeled in LabVIEW environment to interface the device by extracting the input signals through Data Acquisition Card (DAQ).The perception received from different surface conditions (like rough, smooth, soft) by the sensors are recorded and stored in the form of look up table which would be used in the developing human- machine interface for the device.

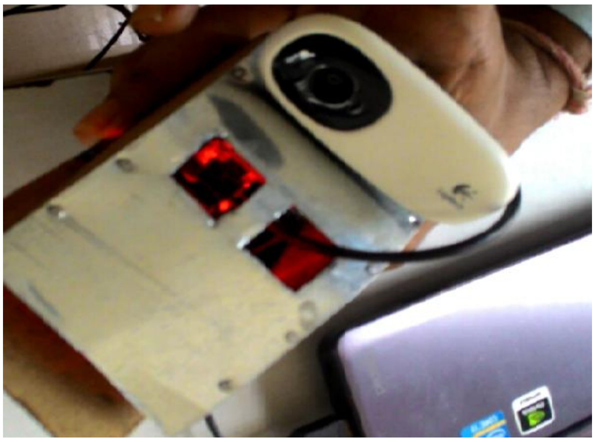

Fig 4: Puck Scanner

The data obtained from the Hand module is used to construct another device called the 'Puck Scanner' for human–machine interaction in virtuality. The device is as shown in fig 4. This device consists of an image scanner or a camera, an ERM actuator along with an ARM cortex M3 processor.

The puck scanner is used for the purpose of feature extraction and feature matching. These are the two important processes that form the basis for virtuality in haptics. They are explained below:

A. Feature Extraction

In Feature Extraction method, image scanner or a Camera captures a 2-D image on the virtual surface. The image matrix and position of the device on the matrix are passed as parameters to the processor on the embed board. A position sensor is used to ascertain the position of the device on image matrix. This is achieved using object recognition system. It consists of 3 stages:

Preprocessing followed by Feature Extraction and Feature Matching. In order to remove noise from the scanned image, preprocessing is carried out using Gabor filter given by eq(1).

$$G(x, y; \theta, f) \exp\left\{-\frac{1}{2}\left[\frac{x_\theta^2}{\sigma_x^2}+\frac{y_\theta^2}{\sigma_y^2}\right]\right\}\cos(2\pi f x_\theta)$$

Where, $x_\theta = x\cos\theta + y\sin\theta$

$$y_\theta = -x\sin\theta + y\cos\theta \qquad \text{eq (1)}$$

B. Feature Matching

The features extracted from the captured image are matched with the features of the image in the database, Feature extraction is done in MATLAB using MSER (Maximally Stable External Regions) extraction algorithm. Features are nothing but changes in intensity levels or surface textures usually called edges or blobs. A particular frequency is generated corresponding to that feature. This frequency is different for different surfaces or textures. Frequency readings are recorded from the previous device i.e., hand module for real- time and virtual time comparison of frequencies The pixel values of the feature extracted images are in the range of 0 to 255.Pixel values are higher for brighter image and lower for a lower intensity images. These values are divided into three ranges, with each range actuating the actuators with a particular frequency, giving a sense of real feel to the blind users about the surface variations in virtual world. The ERM actuators are operated using ARM cortex M3 processor.

IV. SIMULATION AND EXPERIMENTATION RESULTS

The Hand module is pressed against the wooden surfaces. The applied pressure is converted into resistance output by the FSR sensors which are tabulated in Table 1, this table gives the detail about changes in the resistance with respect to the time and it varies as the pressure is increased.

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Table 1: Output recorded from Hand Module for different positions and different pressures.

Time	Resistance
0.00000E+0	9.99981E-2
1.00000E-5	2.77251E-1
2.00000E-5	4.51724E-1
3.00000E-5	6.20642E-1
4.00000E-5	7.81323E-1
5.00000E-5	9.31269E-1
6.00000E-5	1.06809E+0
7.00000E-5	1.18968E+0
8.00000E-5	1.29406E+0
9.00000E-5	1.37960E+0
1.00000E-4	1.44500E+0
1.10000E-4	1.48918E+0
1.20000E-4	1.51141E+0
1.30000E-4	1.48915E+0
1.40000E-4	1.44498E+0
1.50000E-4	1.37960E+0
1.60000E-4	1.29405E+0
1.70000E-4	1.18967E+0
1.80000E-4	1.06809E+0
1.90000E-4	9.31254E-1
2.00000E-4	7.81294E-1

The plot of Resistance and slope shown in Fig 5 represents the resistance variation when subjected to different pressure at the different depth areas also this graph is verified according to the datasheet of FSR sensor the data obtained is 98% accurate and these values are recorded and further used to build the second module in the proposed algorithm.

Fig 5 shows the response of the table and results were captured in LabVIEW environment .this step was particularly done just to know how the surface interacts under different pressure conditions and Fig 6showsthe image of wooden surface chosen for the proposed project with different depth criteria.

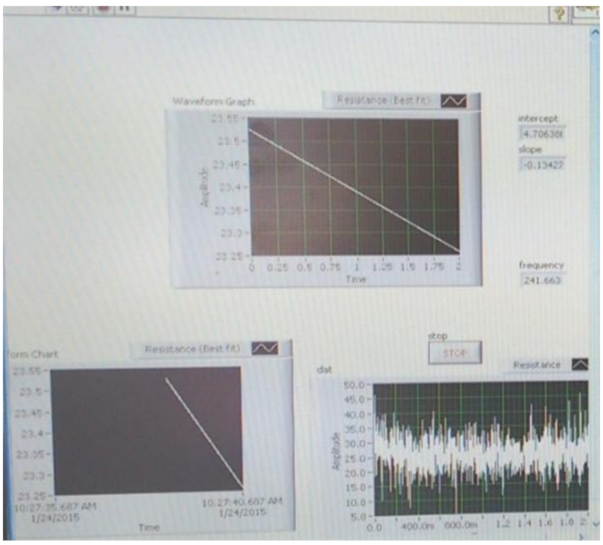

Fig 5: Plot of slope and applied pressure.

Fig 6: Surface of wooden texture

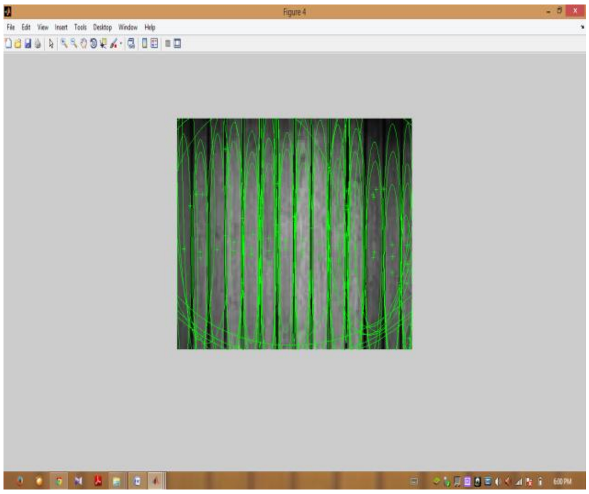

Fig 7: Feature extraction of the wooden surface

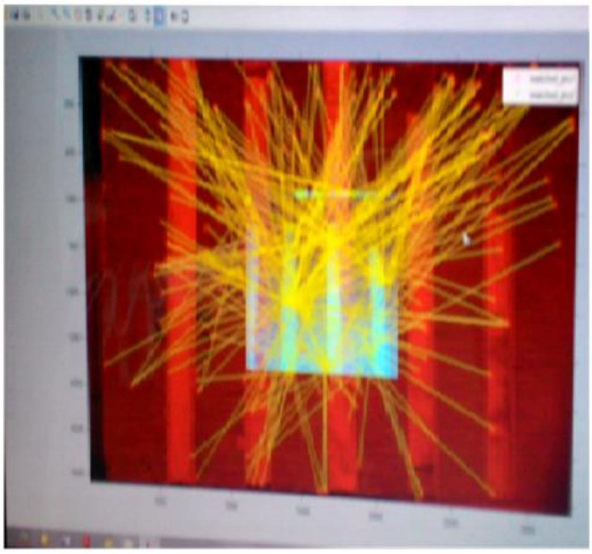

Fig 8: Feature matching for surface

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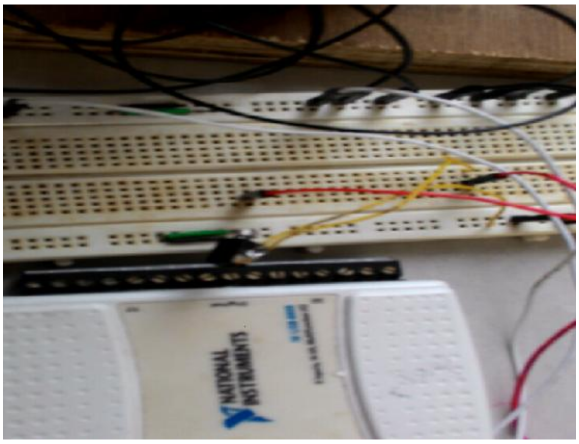

Fig 9: Actuation of ERM Actuators in real time

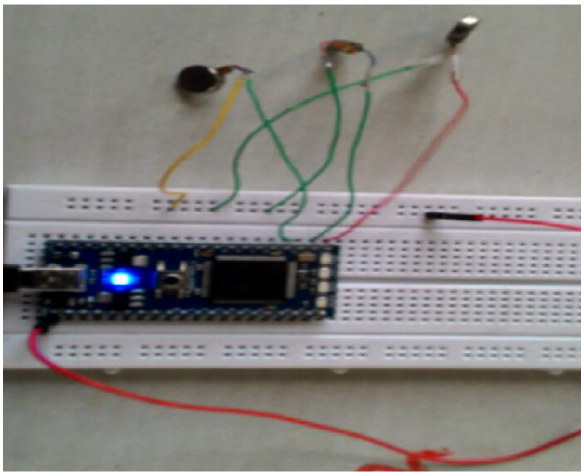

Fig 10: Actuation of ERM motors

Fig 7 provides an information about the feature extraction carried during object recognition step and these results matched with database with 96% during the feature matching step which is depicted in the Fig 8.
Once the match was found the algorithm checks for pixel intensity based on user position and provides a particular amount of vibration and these vibration are previously defined according to the values obtained from hand module (Ref Fig 3), for this vibration ERM motors were used. Fig 9 and Fig 10 shows the hardware interface of these motors.
After all the results were obtained the module was tested on ten persons 7 out of 10 felt the vibration when they scanned the virtual surface and based on their input the module was improvised and the results of the same are shared in this paper

V. CONCLUSION AND FUTURE WORK

Finally one can conclude that the two Haptics modules developed helps the user to feel the behavior and texture of different surfaces in a virtual environment providing a sense of touch as though one is physically in contact with a surface. Further the above work can be extended to study various other surfaces so as to enhance tactile sense or Haptics touch in the virtual environment.

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