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MEMS SENSORS CONTROLLED HAPTIC FOREFINGER ROBOTIC AID

Varalakshmi B D[1], Abhilasha Pachauri[1], Thriveni J[1], Venugopal K R[1], Patnaik L M[2]

[1]Department of CS & E, UVCE.
[2]Honorary Professor, IISc.

ABSTRACT

The ability to feel the world through the tools we hold is Haptic Touch. The concept of sensory elements transforming information into touch experience by interacting with things remotely is motivating and challenging. This paper deals with the design and implementation of fore finger direction based robot for physically challenged people, which follows the direction of the Forefinger. The path way of the robot may be either point- to-point or continuous. This sensor detects the direction of the forefinger and the output is transmitted via RF transmitter to the receiver unit. In the receiver section RF receiver which receives corresponding signal will command the microcontroller to move the robot in that particular direction. The design of the system includes microcontroller, MEMS sensor and RF technology. The robot system receives the command from the MEMS sensor which is placed on the fore finger at the transmitter section. Therefore the simple control mechanism of the robot is shown. Experimental results for fore finger based directional robot are enumerated.

Keywords: Robotic Body, Wireless Technology, MEMS Sensor, Haptics.

1. INTRODUCTION

Haptics allows the users to “touch” and “feel” the objects which we can interact. It is a recent enhancement to virtual environments allowing users the freedom to touch and feel. Haptics which means, the science of touch is derived from the Greek word haptikos which means “being able to come into contact with”. Virtual reality is a form of human-computer interaction (as opposed to keyboard, mouse and monitor) providing a virtual environment that one can explore through direct interaction with our senses. The study of haptics emerged from advances in virtual reality. To be able to interact with an environment, there must be feedback. For example, the user should be able to touch a virtual object and feel a response from it. This type of haptic feedback includes both tactile and force feedback [1].

Haptics are applied on a wide range of devices. Haptic surgical simulators provide excellent precision, which provide realistic forces that emulate the feel of a real medical procedure. Computer gamers experience added realism to their favourite games with haptic enabled joysticks that allow them to feel every bump, explosion, rumble, burst of gunfire and other vibration-based activity, because of the force feedback.. Haptics is also emerging into cell phone design. The simple act of the phone vibrating when a call is received is the most recognizable and rudimentary form of the haptics technology. The clinical skills of medical professionals can be harvested better as they rely strongly on the sense of touch, combined with anatomical and diagnostic knowledge [1].

1.1 Haptic Terminologies

Some of the haptic terminologies are

Vestibular-	Relates to the perception of head position, acceleration and deceleration
Cutaneous	Relates to the sensation of pressure, temperature and pain
Tactile	Similar to the cutaneous generally but specifically relates to the sensation of pressure.
Proprioceptive	Relates to cutaneous, kinesthetic and vestibular sensations).
Kinesthetic	Relates to the sensations originating in muscles, tendons and joints
Force Feedback	Relates to the mechanical production of information sensed by the human kinesthetic system. [18]

Many different terms with many different definitions are used throughout the literature to describe haptic interaction. One reason for this is that the area is in its infancy. To rectify this problem we propose a set of haptic definitions that should prove useful for further research in this area. The word 'haptic' has grown in popularity with the advent of touch in computing. We define the human haptic system to consist of the entire sensory, motor and cognitive components of the body-brain system. It is therefore closest to the meaning of proprioceptive.

Haptics can be broadly defined as anything related to the sense of touch. Haptic information can be cutaneous and kinesthetic information. There is some overlap between these two categories; critically both can convey the sensation of contact with an object. The distinction becomes important however when we attempt to describe the emerging technology. In brief, a haptic device provides position input like a mouse but also stimulates the sense of touch by applying output to the user in the form of forces. Tactile devices affect the skin surface by stretching it or pulling it, for example. Force feedback devices affect the finger, hand, or body position and movement. Using these definitions devices can be categorised and understood by the sensory system that they primarily affect.

1.2 Haptic Information

Characterization of the nature of haptic information, and how it is perceived, is necessary to understand how medical professionals use haptics to enable learning and achieve high levels of performance. Papers that explore haptic models of the patient, as well as perceptual or behavioural aspects of the haptic modality relevant to medical examinations and procedures, are solicited. Haptic systems and the role of haptics in training and evaluating clinical skills: Haptic simulators address a growing need for effective training and evaluation of clinical skills [3]. Such simulators can be applied in a wide variety of medical professions and disciplines, including surgery, interventional radiology, anaesthesiology, dentistry, veterinary medicine, and the allied health professions. These simulators rely on both technology development (devices, software, and systems) and an understanding of how humans use haptic feedback to perform established clinical skills or learn novel skills. Papers that address simulator development and/or evaluation from these perspectives are solicited [1] [3].

1.3 Motivation, Contribution and Organization

Motivation: The need to develop a simple yet effective module with low cost and user effectiveness for the need of physically challenged people.

Contribution: The proposed model is aimed at providing the basis for developing devices which are aimed at physically challenged people and people with less mobility.

Organization: This technical paper is organized as follows: In Section 2 we present an overview of the related work of the fore finger based, Section 3 gives the inspiration, Section 4 explains the system Architecture, Section 5 gives the Hardware Design, Section 6 gives the System Implementation, Section 7 includes the snapshots of the work and Section 8 concludes the paper with Future enhancement discussion.

2. RELATED WORKS

2.1 Haptic Technology

Haptic Technology is the only solution which provides high range of interaction that cannot be provided by virtual reality. The touch access technology is important till now. But Haptic technology has totally changed this trend. This technology makes the future world as a sensible one. Haptic technology enables users to simulate touch and utilize a new input as well as output technology. Haptic Technology has a large scope in gaming and other applications including pleasures. If the Haptic devices can be made more modular and simpler which in term makes them lighter, simpler and easier to use who use them in gaming or other use [17].

2.2 Haptics in Robotics

In this paper, the main contribution is a novel controller that enables a robot arm to move within an environment, while regulating contact forces across its entire surface. We present progress towards new foundational capabilities for robot manipulation that take advantage of contact across the entire arm. Humans make extensive contact with their forearms even during mundane tasks, such as eating or working at a desk.. For example, when reaching into a bush, moderate contact forces are unlikely to alter the robot's arm or the bush in undesirable ways.

While some situations merit strict avoidance of contact with an object, we consider these to be rare, and instead focus on control methods that allow contact. The primary assumption is that, for a given robot, environment, and task, contact forces below some value have no associated penalty. Likewise, even environments with fragile objects, such as glassware on a shelf, can permit low contact forces. The controller assumes that contact forces can be sensed across the surface of the arm, and that the arm's joints can be modelled as linear torsion springs. At every step a quadratic programming problem is solved that minimizes the predicted distance to a goal, subject to constraints on the predicted changes in contact forces [12].

2.3 Haptic Arms

One of the critical aspects of understanding dexterity is the analysis of the relationships between the hand muscle movements and joint movements, defined by the moment arms of the muscles.. Human level of dexterity has not been duplicated in a robotic form to date. We have developed an anatomically correct test bed (ACT) hand to investigate the importance and behavioural consequences of anatomical features and neural control strategies of the human hand. It is known that the moment arms for the hand muscles are configuration-dependent and vary substantially with change in posture. Dexterity is achieved in part due to the biomechanical structure of the human body and in part due to the neural control of movement.

We present the implications of the determination of variable moment arms toward understanding of the biomechanical properties of the human hand and for the neuromuscular control for the ACT hand index finger movements GPs give a functional mapping between the joint angles and muscle excursions, and the gradients of these mappings are the muscle moment arms. To determine variations in the moment arms of the ACT hand index finger muscles, we employed a nonparametric regression method called Gaussian processes (GPs). We compared the moment arm relationships of the ACT hand with those determined from the available cadaver data. [16].

2.4 Social Robots

There is a growing trend of robots that socially interact with people (e.g. [1-6]). Likewise there are now robots that can assist in the provision of care and therapy to children, elderly, and a typical population (e.g. [7-9]). Such kinds of robots are called social robots. Social robots are autonomous robots that are able to interact and communicate among themselves, with humans, and with the environment and are designed to operate according to the established social and cultural norms. For robots to achieve socially engaging interactions with humans, researchers have argued that robots are expected to learn and produce human-like attributes such as body movements [13-15].

So far, the majority of the works were on the modelling of robots/machines which can understand human facial expressions, hand gestures, and body movements. Another paradigm is the programming of robots by demonstration. The robot then processes the data through various machine learning algorithms and the gestures are replicated. To complement the initial data from the wearable sensors, some researchers have also taught robots by physically moving the robot's limbs to the desired positions or to correct the initial motion from the wearable sensors, i.e. kinaesthetic teaching [19].

2.5 Haptics in Wearable devices

In this paper a novel 3-DoF wearable haptic interface is designed that introduces design guidelines for wearable haptics and presents a method to apply force directly to the fingertip. The structure of the device resembles that of parallel robots, where the fingertip is placed in between the static and the moving platforms. It consists of two platforms: a static one, placed on the back of the finger, and a mobile one, responsible for applying forces at the finger pad. The device can exert up to 1.5 N, with a maximum platform inclination of 30 degree.

To validate the device and verify its effectiveness, a curvature discrimination experiment was carried out: employing the wearable device together with a popular haptic interface improved the performance with respect of employing the haptic interface alone [20]. Wearability will significantly increase the use of haptics in everyday life, as has already happened for audio and video technologies. The literature on wearable haptics is mainly focused on vibrotactile stimulation, and only recently, wearable devices conveying richer stimuli, like force vectors, have been proposed.

3. INSPIRATIONS FOR THE WORK

3.1 Haptic Force

The human ability to perceive forces has not been documented well enough, though force-feedback devices are already being used. The haptic perception of force direction and magnitude has mostly been studied in discrimination tasks in the direction of gravity. In our study, the influence of physical force direction on haptic perception of force magnitude and direction was studied in the horizontal plane. Subjects estimated the direction and magnitude of a force exerted on their stationary hand. A significant anisotropy in perception of force magnitude and direction was found. Force direction data showed significant subject-dependent distortions at various physical directions.
This pattern could be related to arm stiffness or manipulability patterns, which are also ellipse-shaped. These ellipses have an orientation consistent with the distortion measured in our study. So, forces in the direction of highest stiffness and lowest manipulability are perceived as being smaller. It therefore seems that humans possess a "sense of effort" rather than a "sense of force," which may be more useful in everyday life. These results could be useful in the design of haptic devices. The sensor which is placed on our fore finger operates when the direction of the finger changes. Finite element analyses using human finger model during dynamic touch showed that spatial information of the textured surface are related to temporal frequency changes at the position of tactile receptors [2]-[6].

In touch activities, if humans have the ability to estimate somehow the relative hand velocity v between the textured surface and the exploring finger, the spatial period Δp of the surface can be perceived by detecting the temporal frequency of the vibration [7], such that:

$$f = v / \Delta p \qquad (1)$$

In artificial touch, when considering technological approaches in which mechanical sensing elements are embedded in skin-like elastomeric matrices that mimic human skin, such vibrations should be elicited by stimulus skin interface, by motion dynamics and by contact mechanics, and then gathered by the sensing units located under the covering material [8]-[10].Stimuli when applied in the horizontal direction against the surface of the skin-like tactile arrays may result in a more effective deformation of the sensor element with a fingerprint-type surface than that with a smooth surface [11].

3.2 MEMS Sensor

MicroElectroMechanical systems (**MEMS**) (also written as micro-electro-mechanical, micro machines (in Japan), Micro system technology (MST in Europe), MicroElectroMechanical or microelectronic and MicroElectroMechanical systems) is the technology of very small devices; it merges at the nano-scale into NanoElectroMechanical systems (NEMS) and nanotechnology [15]. It has been shown that MEMS based tactile sensors can be designed and built with a 3D structure that can adequately be packaged with skin like polymeric materials so that the sensor and soft packaging become a new tactile sensible element like the Soft and Compliant Tactile Micro sensor reported in [13].MEMS sensor array and electronics for integration in a robotic finger is as shown in Figure 1a. The Sensor has been mounted on a forefinger. A close up view of the MEMS Sensor is also shown in Figure. 1b.

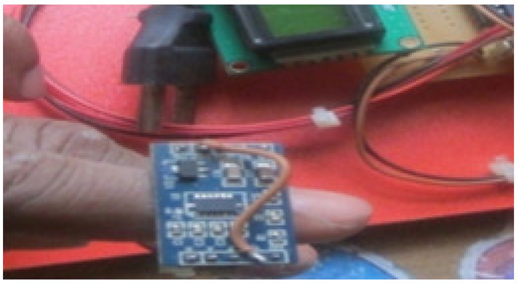

Figure 1a: The MEMS sensor mounted on ForeFinger

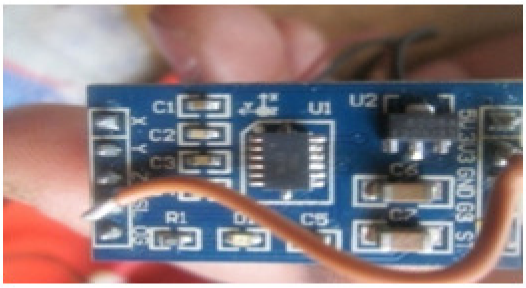

Figure 1b: Close up view of the MEMS sensor

4. SYSTEM ARCHITECTURE

The design (Fig. 2) of the robot consists of AT83S52 microcontroller, L293D driver circuit, RF transmitter and receiver platform of the robot consists of metal chassis, 2 DC motors are used to control the wheels. The body is interfaced with RF receiver section and microcontroller. It receives the signals from the RF Transmitter section and operates the wheels of the robot where it can move in all the four directions i.e.(forward, reverse, right and left). The transmitter section consists of MEMS sensor (Fig. 1b) which is placed on fore finger, operates by changing the directions of the finger (i.e. lower 90- forward, upper 90-reverse, clock wise 60-right, anti clock wise 60-left). These directional changes will be transmitted to RF receiver at receiver section which is placed on robot platform.

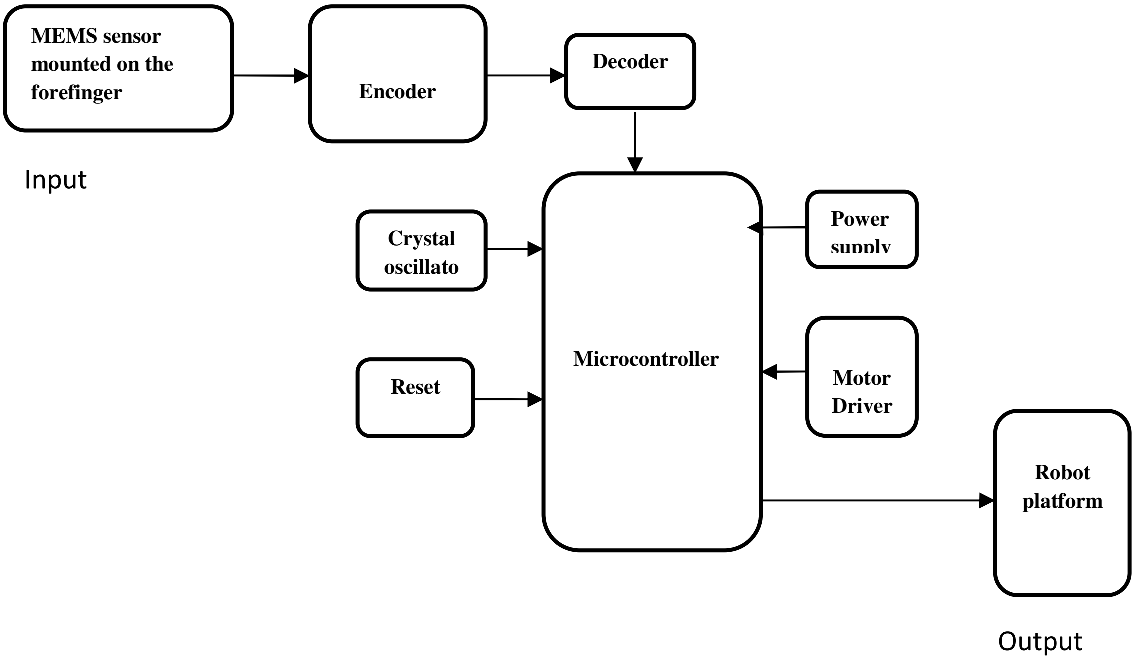

Figure 2: System Architecture

5. HARDWARE DESIGN

The Hardware design consists of robot, microcontroller unit, MEMS sensor, LCD unit, and RF transmitter and receiver unit. Robot platform is built up with metal chassis, 2 wheels attached to 2 DC motors, a load balancer and L293D driver circuit as shown in Figs. 3(a)-(b). The DC motor of

+12v, 60rpm is used for robot movements. The motors are driven by motor Drivers based on the signal generated by microcontroller. L293D driver circuit is based on H-bridge concept, which is an electronic circuit, enables a voltage to be applied across a load or motor in either direction. The H-bridge concept is generally used to reverse the polarity of DC motor, or causes a break where the terminals of the motor are shorted or to let the motor free run to stop. Table 1 summarizes the operation of H-bridge with H-L corresponding to Fig 3(b).

Figure 3(a): Dc motor of 12V, 60 rpm

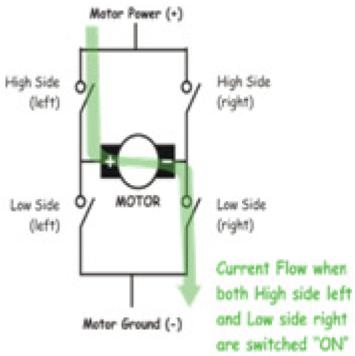

Figure 3(b): H-bridge

5.1 Pin Diagram of L293D

Both enable 1 and enable 2 of Micro Controller are shorted to V_{cc} (+5v) as the output of micro controller is too low to drive the DC motor. However this problem can be overcome by the use of driver circuit L293D as in Table 1 as it provides the current which is sufficient to drive the DC motor.

Table 1: L293D Truth Table

Input		Functions
V_{en}=High	C=High D=Low	Forward
	C=Low D=High	Reverse
	C=Don’t Care	Fast Motor Stop
V_{en}=Low	C=D=Don’t Care	Free Running Motor Stop

AT89S52 is a low-power, high-performance 8-bit microcomputer with 8K bytes of Flash programmable and erasable read only memory (PEROM). The on-chip Flash allows the program memory to be reprogrammed in-system or by a Conventional non-volatile memory programmer.

5.2 Power Supply Unit

The circuit needs two different voltages, +5V & +12V to work. These dual voltages are supplied by this specially designed power supply. This regulator IC comes in two flavours, As shown in Figure 4, 78xx for positive voltage output and 79xx for negative voltage output. For example 7812 gives +12V output and 7912 gives -12V stabilized output. These regulator ICs have in-built short-circuit protection and auto-thermal cut out provisions.

6. IMPLEMENTATION OF THE PROJECT

Algorithm of Working of Forefinger Robot

Step 1. Whole Module is initialized
Step 2. LCD on the transmitter kit will display the status of the module
Step 3. The MEMs sensor which operates between 0 to 3.3V will transmit the information according to the variations done, which is analog value and it is given to ADC.
Step 4. From ADC, input is given to Microcontroller which transmits the information through RF transmitter to remote location
Step 5. RF receiver, receives the information and decodes it and sends to Microcontroller through which L293D driver circuits H-Bridge is controlled
Step 6. The information from the H-Bridge will control the DC motor of the Robot.
Step 7. MEMs operate under a minimum value of 0V and maximum of 3.3V.
Step 8. When MEMs is 60^{o} degree towards right, it will be operated from 0V to 1V.(The Robot moves in RIGHT Direction)
Step 9. When MEMs is 60^{o} degree towards the left, the voltage varies from 1V to 1.5V. (The Robot moves in LEFT Direction)
Step 10. When MEMs is 90^{o} upwards, it will be operated in 1.5V to 2.5V. (The Robot moves in FRONT Direction)
Step 11. When MEMs is 90^{o} downwards, the voltage varies from 2.5V to 3.3V. (The Robot moves in BACKWARD Direction)
Step 12 When MEMs is at 0^{o}. (The Robot is in STOP position)
Step13 The varied analog value from the MEMs sensor is given to ADC which will be converted to Digital Value

7. SNAPSHOTS OF THE ROBOT

Figure 8: Snapshot of the Receiver Section

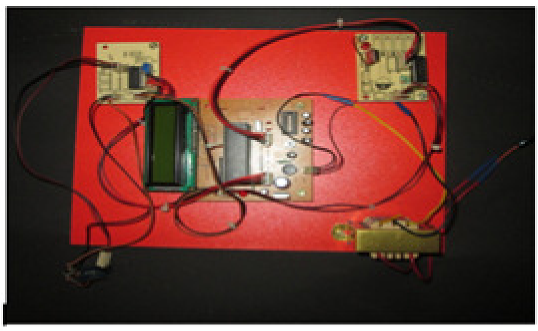

Figure 9: Snapshot of the Transmitter Section

8. CONCLUSIONS

In this paper we have implemented a robot which can be used by patients and people with less mobility to move the wheel chair by using gyro sensors- MEMS Sensors in particular. The design of the system includes microcontroller, MEMS sensor and RF technology. The MEMS sensor is placed on the fore finger at the transmitter section which moves the Robot in the direction of the Forefinger direction. This sensor detects the direction of Forefinger and the output is transmitted via RF transmitter. In the receiver section RF receiver receives corresponding signal and will command microcontroller to move the robot in that particular direction. Experimental results for fore finger based directional robot are enumerated.

A. Future Enhancements

Design and implement a few haptic related projects for the benefit of physically challenged people. This proposal develops an approach for haptic exploration of unknown objects by robotic fingers. Because haptic exploration is coupled with manipulation and exploration using a sequence of phases is presented. With specialized fingers and sensors and appropriate planning and control robots can also be enabled to explore the worlds through touch.

Scope and Applications: Haptic exploration has applications in many areas including planetary exploration, undersea operations, operations in remote and hazardous conditions. Applications of the human haptic interaction, multi-sensory perception, action and multimodal feedback can be applied in the fields of education, rehabilitation, medicine, computer aided design, skill training, computer games, driver controls, simulation and visualization [21].

Haptics research has permeated many disciplines and application areas. Earliest efforts focused on sensory substitution: stimulating the sense of touch to convey imagery or speech for individuals with visual and/or auditory impairments. With the advent of force-feedback devices, there have been renewed interests in using haptic interfaces in teleoperator systems and virtual environments.

The successful deployment of haptic interfaces requires continuing advances in hardware design, control, software algorithms, as well as our understanding of the human somato sensory system. Priority areas include, but are by no means limited to:

1. Sensory guided motor control
2. Tactile display and tactile sensing
3. Devices & Technology
4. Neuroscience
5. Haptic Communication
6. Haptic rendering
7. Perception & psychophysics
8. Haptic cognition
9. Multimodal perception

Applications in entertainment, gaming, medicine, rehabilitation, education, data perceptualization, art, rapid prototyping, remote collaboration, etc. [22].

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