TACTILE SENSING FABRICS FOR DETECTING IMPAIRMENTS IN LEPROSY PATIENTS

Sathish Kumar Paul †, V Rekha PhD ^ & Sudesh Sivarasu PhD*  

† The Leprosy Mission, New Delhi, India  
^VIT University, India  
* Biomedical Engineering, University of Cape Town, South Africa – 7925  
sudeshsivarasu@gmail.com

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Abstract

There has been a rising need for developing a rehabilitation device for patients with leprosy, as most of the present day approach is towards the eradication of the disease. To assist and monitor the extent of damage of a nerve and muscle cells, a new fabric embedded tactile sensor incorporated in gloves and other smart fabrics are used. By incorporating tactile sensing in the gloves, and recording the information off the gloves, the results were evident in showing the effect of prolonged usage of any particular part of the limbs.

1 Introduction

Leprosy is primarily a granulomatous disease of the peripheral nerves and mucosa of the upper respiratory tract; skin lesions are the primary external sign. Left untreated, leprosy can be progressive, causing permanent damage to the skin, nerves, limbs and eyes. Contrary to folklore, leprosy does not cause body parts to fall off, although they can become numb or diseased as a result of secondary infections; these occur as a result of the body's defenses being compromised by the primary disease. Secondary infections, in turn, can result in tissue loss causing fingers and toes to become shortened and deformed, as cartilage is absorbed into the body.

Being known the virulence of this disease, most of the research is based on its cure. Some of the existing treatments include drug therapy and chemotheraphy. Also steps are being taken to eradicate and to a larger extend control its spread. A step towards rehabilitation is yet to catch up its pace.

2 Background and Need of the Work

Leprosy is also called Hansen's disease. Leprosy is caused by the organism Mycobacterium leprae. It is defined as a chronic bacterial disease affecting mainly skin and nerves. If untreated, there can be progressive and permanent damage to the skin, nerves, limbs and eyes. It is a major public health problem in most of the developing world and is often found in conditions connected with poverty, overcrowding, poor sanitation and insufficient nutrition. According to current World Health Organization’s data, the current global prevalence rate is around 1.4 cases per 10,000 people. Around 5, 00,000 new cases of leprosy are registered each year. India alone has about 5, 00,000 infected people, which represents 63% of the global occurrences. Leprosy, a chronic infectious disease that, if left untreated, can cause debilitating deformities and slowly progress throughout one's life. It is characterized by peripheral nerve damage, cutaneous lesions and a wide range of clinical manifestations.

The major side effects are permanent disability of hands, feet or eyes. Leprosy can damage the peripheral nerves and nerves in the skin. This damage can lead to loss of sweat and oil gland function which causes dry and cracked skin on the hands and feet, loss of the ability to feel light touch or, with more severe damage, loss of protective sensation, weakness of the eyelids, preventing proper closure of the lid which protects the eye, loss of strength in the hands and feet. In order to contract the disease, one has to live in close contact with an infected individual for a prolonged amount of time. These physical effects paired with the social stigma of being infected with this dreaded disease, often lead to those affected being afraid to come forward to seek treatment in the early stages of the disease. Hence there arises a need for rehabilitation.

The basic concepts behind rehabilitation are that the persons affected with leprosy should be restored back to normal social life or as near as possible. Rehabilitation means restoration of economic productivity leading to economic independence. In India economic independence out weigh many other considerations. Rehabilitation in the field of leprosy requires greater efforts than the rehabilitation in other types of disabled persons because the question of social acceptance does not arise in non leprosy disabled persons. In the case of a orthopedically handicapped or a blind or deaf person their stay with the family is not prejudiced as in the case of leprosy patients. This is due to the stigma attached to the disease.
Neuropathy a defect in the nerve function leads to the changes in the structure and the function of certain parts of the body. When the patient loose the sensory perception it is difficult to recognize the stresses which in a normal person will lead to withdrawal when burnt or rest when injured. This leads to the neglect of abnormal pressures, friction, burns resulting in minor trauma and delay in healing of damaged tissues leading to ulcers. High sensing capabilities in certain animals like the bats, spiders and cats in sensing help their survival likewise tilt sensing and tactile sensing on various parts of the human anatomy belong to low performance sensing system (1). Finding suitable technological analogies for complex tactile senses are difficult considering the wider area it covers than by the other localized sense organs like the eyes and the ears (2, 3).

The tactile receptors in the body when stimulated are able to adapt at a faster rate and are able to respond to the changes in the external stimuli like the pressure and temperature (5). Mechanoreceptors (for pressure/vibration), thermo receptors (for temperature) and nocioceptors (for pain/ damage) located in the various layers of the skin provide support and protection from the external environment. The Merkel Disks and the Ruffini endings located superficially and in the subcutaneous tissue are excited by any stimulus on the skin (6). The mechanoreceptors which can be categorized as Rapid adaptors (RA) and slow adaptors (SA) respond to the various stimulations like the force, position and size, softness/hardness and roughness and texture via various complicated pathways to the brain (7).

Sensors interface with the environment, similar to the five human senses of hearing, smell, touch, vision, and taste, to stimulate a suitable response or action. Among the first four senses, touch remains the most challenging sense to emulate, where capabilities on a par with a human finger are required. The difficulty lies in designing a high-resolution device that can be mounted on a curved surface and also sense a distribution of stimuli at high spatial resolution over a large area of contact. For example, a human finger – the most sensitive touch sensor known – can feel texture by detecting surface roughness at a spatial resolution of about 40 μm over a contact-area of approximately 1 square centimeter and at stress levels of 10–40 KPa; in contrast, current sensor devices have a resolution of 2 mm for a similar contact area (6).

Customized software was developed and the tactile sensory parameters be recorded while involving the patients in their activities of daily living. Distribution pattern of these parameters were traced and evaluated with existing injury pattern.

The study was done on patients (n=100) from different job profile, gender and from different geographical location and checked for any prominent deviation from the existing injury patterns.

3. Artificial Mimicking of Human tactile Sensing

This research helped in the measurement of the variable contact forces that occur during the manipulators interaction with the other biological tissues (8). This was measured by various miniaturized sensors embedded uniformly as matrices into elastic materials on the hand and the feet. Based on the information available on the senses of the human hand necessary/ desirable features of any component tactile sensor will be primarily extracted. Among these features are spatial resolution, force sensitivity and dynamic range, linearity/hysteresis, temporal resolution, and robustness.

Taking into consideration the human fingertip, an artificial tactile sensor would require an array of sensors with spatial resolution of about 1-2mm (4). A sensitivity range of 0.01-10 Neutons would be required for the force sensitivity and dynamic range parameter (7). The hysteresis should be kept low by getting an output which will be stable, monotonic and repeatable from the tactile sensors. The sensor needs to be robust and should withstand harsh environments in terms of temperature, humidity, radiation, and chemical stresses.

Tactile display or a feedback system is necessary along with a proper data acquisition system for the process of converting and transmitting the sensor signal into actuation so that it can be felt and the patient can respond. Development of indigenous technology can alone aid the disease profile development (12).

4 Electronics Design & Component Selection

4.1 Usage of Temperature Sensors

Temperature measurement is very important in all spheres of life. Taking a temperature essentially requires the transmission of a small portion of an object’s thermal energy to the sensor, whose function is to convert that energy into an electrical signal. When a contact sensor (probe) is placed inside or on the object, heat conduction takes place through the interface between the object and the probe. Contact temperature sensors measure their own temperature. One infers the temperature of the object to which the sensor is in contact by assuming or knowing that the two are in thermal equilibrium, that is, there is no heat flow between them. Non Contact Sensors - Most commercial and scientific non contact temperature sensors measure the thermal radiant power of the Infrared or Optical radiation that they receive from a known or calculated area on its surface, or a known or calculated volume within it (in those cases where the object is semitransparent within the measuring wavelength passband of the sensor). One then infers the temperature of an object from which the radiant power is assumed to be emitted (some may be reflected rather than emitted).
4.2 LM35 (Precision Centigrade Temperature Sensors)

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1/4°C at room temperature and ±3/4°C over a full −55 to +150°C temperature range. Low cost is assured by trimming and calibration at the water level. The LM35’s low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 μA from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 is rated to operate over a −55°C to +150°C temperature range.

4.3 Pressure Sensor

Flexi force pressure sensors can measure force between almost any two surfaces and is durable enough to stand up to most environments. Flexi force has better sensor properties, linearity, hysteresis, drift and temperature sensitivity than any other thin film force sensor. Its single element sensor acts as a resistor in an electrical circuit. When the sensor is unloaded, its resistance is very high. When a force is applied to the sensor, this resistance decreases. The resistance can be read by connecting an ohm meter to the outer two pins of the sensor connector and applying a force to the sensing area. There are many ways to integrate the sensor into an application(13). One way is to incorporate it into a force-to-voltage circuit. A means of calibration must be established to convert the output into the appropriate engineering units. Depending on the setup, an adjustment could then be done to increase or decrease the sensitivity of the sensor.

The Flexi Force sensor is an ultra-thin and flexible printed circuit, which can be easily integrated into most applications. With its paper-thin construction, flexibility and force measurement ability, the Flexi Force force sensor can measure force between almost any two surfaces and is durable enough to stand up to most environments. The Flexi Force has better force sensing properties, linearity, hysteresis, drift, and temperature sensitivity than any other thin-film force sensors. The “active sensing area” is a 0.375” diameter circle at the end of the sensor. The sensors are constructed of two layers of substrate. This substrate is composed of polyester film (or Polyimide in the case of the High-Temperature Sensors). On each layer, a conductive material (silver) is applied, followed by a layer of pressure-sensitive ink. Adhesive is then used to laminate the two layers of substrate together to form the sensor. The silver circle on top of the pressure-sensitive ink defines the “active sensing area.” Silver extends from the sensing area to the connectors at the other end of the sensor, forming the conductive leads. FlexiForce sensors are terminated with a solder able male square pin connector, which allows them to be incorporated into a circuit. The two outer pins of the connector are active and the center pin is inactive. The length of the sensors can be trimmed by Tekscan to predefined lengths of 2”, 4” and 6” or can be trimmed by the customer. If the customer trims the sensor, a new connector must be attached. This can be accomplished by purchasing staked pin connectors and crimping tool. A conductive epoxy can also be used to adhere small wires to each conductor. The sensor acts as a variable resistor in an electrical circuit. When the sensor is unloaded, its resistance is very high (greater than 5 Meg-ohm); when a force is applied to the sensor, the resistance decreases. Connecting an ohmmeter to the outer two pins of the sensor connector and applying a force to the sensing area can read the change in resistance. Sensors should be stored at temperatures in the range of 15°F (-9°C) to 165°F (74°C).

5 Microcontroller Programming

5.1 ATmega16

The ATmega16 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega16 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus...
processing speed. The ATmega16 provides the following features: 16 Kbytes of In-System Programmable Flash Program memory with Read-While-Write capabilities, 512 bytes EEPROM, 1 Kbytes SRAM, 32 general purpose I/O lines, 32 general purpose working registers, a JTAG interface for Boundary scan, On-chip Debugging support and programming, three flexible Timer/Counters with compare modes, Internal and External Interrupts, a serial programmable USART, a byte oriented Two-wire Serial Interface, an 8-channel, 10-bit ADC with optional differential input stage with programmable gain (TQFP package only), a programmable Watchdog Timer with Internal Oscillator, an SPI serial port, and six software selectable power saving modes.

The Idle mode stops the CPU while allowing the USART, Two-wire interface, A/D Converter, SRAM, Timer/Counters, SPI port, and interrupt system to continue functioning. The Power-down mode saves the register contents but freezes the Oscillator, disabling all other chip functions until the next External Interrupter Hardware Reset. In Power-save mode, the Asynchronous Timer continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping. The ADC Noise Reduction mode stops the CPU and all I/O modules except Asynchronous Timer and ADC, to minimize switching noise during ADC conversions.

In Standby mode, the crystal/resonator Oscillator is running while the rest of the device is sleeping. This allows very fast start-up combined with low-power consumption. In Extended Standby mode, both the main Oscillator and the Asynchronous Timer continue to run. The device is manufactured using Atmel’s high density nonvolatile memory technology. The On chip ISP Flash allows the program memory to be reprogrammed in-system through an SPI serial interface, by a conventional nonvolatile memory programmer, or by an On-chip Boot program running on the AVR core. The boot program can use any interface to download the application.

Program in the Application Flash memory. Software in the Boot Flash section will continue to run while the Application Flash section is updated, providing true Read-While-Write operation. By combining an 8-bit RISC CPU with In-System Self-Programmable Flash on a monolithic chip, the Atmel ATmega16 is a powerful microcontroller that provides a highly-flexible and cost-effective solution to many embedded control applications. (14)

5.2 Programming the GIU

The programming part is done in Smart Software which is supported by .Net program. The objective of the program is to obtain the temperature and pressure values at every instance and plot two graphs:
- temperature vs time
- pressure vs time

and all to switch on the alarm and LED when the values exceed the threshold as given above. These values are then exported to the excel sheet for statistical analysis.
6. Results & Conclusion

The glove or the sock with the sensors embedded were applied to the individual patients having anesthetic limbs due to Neuropathy. The stretchable glove were custom designed and fabricated for the individual patient. The gloves will be worn by patients while doing their normal routine activities. The activities will include cooking, farming and their other normal daily activities. The pressure variations involved in hand and feet during the activities will be recorded and will be compared with the already available data. Studies suggest that the pressure will be high at certain areas of the hand and feet.

Interface pressure measurements have the potential of being a highly useful, practical tool for helping to protect leprotic neuropathic patients from ulceration. This device which is portable will help in the estimation of the incidence of ulcer in patients who are at the community and are not able to come to the hospital.

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