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Material Detecting Glove for Blind People

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Abstract: Blind people identify materials by touching them and decide by the previous experience they have. But this is not an accurate method when some coatings were applied. The aim of this research is to design a material-detecting glove for blind people that will help them to understand and feel better about the surroundings.

While investigating existing literature and technologies which support blind people it was found that many methods were available to avoid obstacles, some to detect the distance, the location, color of an object surface and to read braille but no device to detect materials.

The principal theory behind the design is based on capacitive proximity sensing. First investigated the effects of dielectric constants of different single and two-layer target materials for the variations of sensor head capacitance (ΔC). Then a mathematical function for ΔC was derived using the method of image theory in electrostatics, for two layers of the material case. Then the derived results were verified by simulations in MATLAB®. Finally, plots were obtained, and observations and data required for the design were collected.

A variable was derived which is used for the calibration of the sensor with respect to the different materials and was investigated through experiments carried out. By selecting the appropriate electronic components and utilizing the research data with several testing, the material-detecting glove with wireless communication facility was designed and implemented successfully.

Keywords: Material detection, Capacitive proximity sensing, Dielectric constant

1. Introduction

Eyes are the only human physical body organ to gather environmental data through images. People without clear vision have to depend on others. The number of visually impaired people has been growing over the past decade; about 285 million people are estimated to be visually impaired and nearly 39 million of them are totally blind. Hence, assisting people without clear vision is important and is challenging. Many countries provide special assistance to improve their life quality, thus researchers are motivated to develop devices to overcome their disabilities.

Even though the technologies are available, during the literature review, it was found that recent developments such as hand gloves, band type wearable devices, prototype caps, helmets, stick shape devices and many more have been developed to support blind people. Most of these are to identify the obstacles surrounding them [1], [2], [6], [7] and few of them to track their location [8], to identify printed shapes[9], to detect objects[10] and to detect surface colours[11]. But there is no device developed for the detection of types of materials they are touching. It was observed that, to identify the type of materials of an object, blind people touch the object many times or knock by hand or something and hear the sound then using previous experience to make the decision. But this is not an accurate method when some coatings have been applied.

Therefore, the main objective of this project is to design a low cost, low power and wearable glove equipped with electronic components capable of sensing and detecting various materials. The glove would provide voice signals wirelessly through a Bluetooth module and the design will be helpful for the blind people to experience real world surroundings. The research activity was most useful in data analysis and to find out suitable system development strategies to achieve final design.

2. Literature Review

In recent years, several devices has been developed for the blind people to experience the real world. Most of them are electronic canes, gloves, helmets, caps and band type items which are developed to caution blind people on nearby obstacles and to guide them.

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Abdulrahman etal. [2] had developed an Ultrasonic sensor glove for blind people using Lilypad Arduino which provides guidance to blind people to use right roads using vibration motor and an alarm which alerts the blind on the presence of the object in front of them to avoid collision. This design is a basic level one as it does not have any extra features such as identifying object types, colors, etc.

Goel etal. [6] had proposed a smart hand glove for blind and dumb people; the technique was to help them to recognize nearby obstacles by means of sounds and vibrations. By operating Bluetooth Module (HC-05), 12 sounds and pictures with respect to the patterns given by metal contact switches are enabled on an android application in a smart phone. But it is required to practice well to generate correct message.

Hegdeetal. [7] had proposed smart glasses having an in-built camera which takes pictures and an Ultrasonic sensor for obstacle detection. It can recognize images and determine each object in the images by comparing them with stored data sets. The conversion of captured image type with distance into the voice will be provided to the user as well. But this device could not determine data which is not available in storage and fails to identify the materials of the object too.

A band type wearable device had been proposed by Ibtisam and Annapurna [8]. This detects obstacles on the way using the ultrasonic waves and GPS module which interface with Node MCU to track the location of blind person. But it consumes a lot of time and effort, and this device only detects the obstacles in front.

Mekala etal. [9] had proposed an obstacle and image detection prototype glove using Arduino, Ultrasonic sensors on the left and right side of the glove and IR sensor, which helps the user to avoid obstacles and to identify printed shapes as well. IR sensors are used to find lightness or darkness of a surface and thereby identify the printed shapes through vibration feedback. But the issue is that the user needs to practice for accurate detection of the image using IR sensor.

Nazareth at.al [10] had developed vision gloves to detect objects in indoor places; the first user request received is converted to text and the required object is decided using object algorithm. Then, the speaker notifies whether the object is present or not and raspberry pi analyses the location of the object and vibration motors react to it to guide the user. The main issue is that objects in an open environment are not able to be detected.

Mohamad etal. [11] had proposed a box shape color detector device for identifying colors of a surface with a voice output which operates using matching process between color information and microcontroller database. But the range of detection of the device is limited and the size is not small and compact.

According to the review, all devices were developed for obstacle detection, take care of collision with obstacles, indoor object detection, tracking blind locations, color detection and reading braille, etc. but there is no development for the detection of materials that blind people touch. That is, no one directly belongs to the category which is describing here.

3. Proposed System

3.1 Methodology

In this paper, a methodology is proposed to design a material detecting glove for the blind people. The device is developed by utilizing the data analyzed on variations of capacitance (for the case of capacitive proximity sensing) with respect to the dielectric constant of different types of materials.

The theory behind the design is based on capacitive proximity sensing [4], [5] for the case of mutual mode of capacitance (Figure 2). In this approach, research has been carried out to investigate the effects of dielectric constant, thickness of different single and two-layer target materials and the sensing distance for the variations of sensor head capacitance (ΔC).

At first, a mathematical model for two layers of material configuration (Figure 3) was developed and Gauss's Law, Maxwell's famous equations for the static electric fields and equation for the electric potential due to point charges were applied for this model and a set of equations which governs the system was obtained.

Then, by considering the layered structure of the developed model, equations for the potential on each layer and for the electric field components were derived. Then transformation equations for the image charges were obtained.

Finally, by calculating the potential variation at the sensor head with suitable approximation [4], the required function for the variations of capacitance (ΔC) due to a two-layer object is derived.

This equation was simulated, and different plots were obtained. Then an experiment on variations of potentiometer resistance (R) and voltage (V) values across the RC circuit (instead of measuring ΔC of the capacitive proximity sensor for the detection of selected samples of materials) was carried out for the calibration of the sensor.

Useful and valuable observations and data required for the design were gathered by using the simulation and experimental results. Then hardware implementation, development of the algorithm and programming were done.

When operating the device, if a sensor output is detected, the values of the POT are read by the MCU and make decisions on types of the material and activate the serial communication between Bluetooth modules, then outputs a voice signal mentioning the type of the material.

3.2 Data Flow Diagram

Data flow diagram for the system is shown in Figure 3.

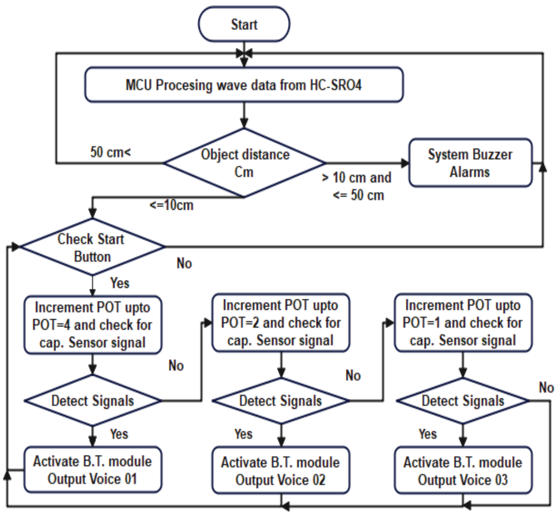


Figure 1 - Data flow diagram for the system

4. Theoretical Analysis

4.1 Development of a Mathematical Model

Here, the capacitive proximity sensing for the case of mutual capacitance mode, when the object consisting of two layers of material as shown in Figure 2 has been considered.

For the derivation of equations, a mathematical model for the two layers of material configuration (Figure 3) was developed by using the method of image theory in electrostatics as follows.

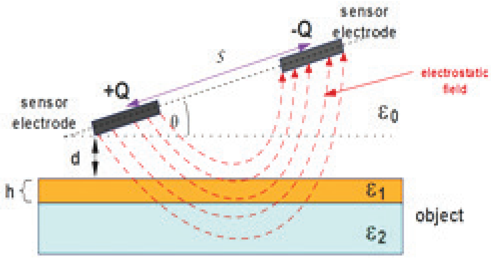


Figure 2 - Capacitive proximity sensing for the case of mutual mode

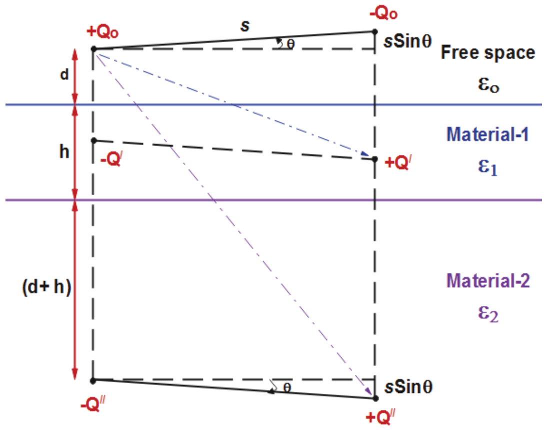


Figure 3 - Mirror charges when the conducting object is far larger than the electrodes

4.2 Derivation of Equation for the Variations of Capacitance

When deriving the function for the variation of capacitance for the case of capacitive proximity sensing for the developed model (Figure 2), electrodes are assumed as point charges and the object is assumed as a conducting plane due to the conducting object is larger than sensor electrodes.

The Gauss's Law, Maxwell's famous equations for the Static electric fields and the equation for electric potential were used. That is,

$$\nabla . E = \frac{\rho}{\varepsilon_0} \quad \text{... (1)}$$

$$\nabla \times E = -\frac{\partial B}{\partial t} \quad \text{... (2)}$$

$$\Phi = \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{r}\right) \quad \text{... (3)}$$

By considering the layered structure of the above implemented model, equations 1 and 2, the equations governing the system under analysis with the electric field E and charge density ρ can be expressed as follows.

For the whole space of system,

$$\nabla\times E = 0 \quad ... (4)$$

For free space which the electrode charge is present,

$$\nabla .\ E = \rho \quad ...(5)$$

For the first and second layers of materials,

$$\nabla .\ E = 0 \quad ... (6)$$

4.2.1. Determination of image charges

A three-layer medium was considered and derivations of equations for the image charges Q/ and Q//were done and relevant equations obtained are,

$$Q^{/} = \frac{(\varepsilon_0-\varepsilon_1)}{(\varepsilon_0+\varepsilon_1)}Q_0 \quad ... (7)$$

$$\boldsymbol{Q^{//}} = \frac{2\varepsilon_1(\varepsilon_1-\varepsilon_2)}{(\varepsilon_0+\varepsilon_1)(\varepsilon_1+\varepsilon_2)}\boldsymbol{Q_0} \quad ... (8)$$

4.2.2 Derivation of equations for the variations of capacitance

Let,

$\emptyset_t$ - Potential on the positive electrode in free space without object

$\emptyset_r$ - Potential on the negative electrode in free space without object

Ψ_t - Potential on the positive electrode in free space with object

Ψ_r - Potential on the negative electrode in free space with object

$Q^{/}$- Image charge of Q_0due to boundary 1

$Q^{//}$- Image charge ofQ_0 due to boundary 2

Comparing the electric field without the object, equations for the potential on the electrodes Ψ_t and Ψ_r were derived by applying equation 3 for the two-layer system.

$$\Psi_t = \Phi_t - \frac{Q^{/}}{4\pi\varepsilon_0}\left\{\frac{1}{2d} - \frac{1}{\sqrt{4d^2+s^2+4ds\sin\theta}}\right\} - \frac{Q^{//}}{4\pi\varepsilon_0}\left\{\frac{1}{2(d+h)} - \frac{1}{\sqrt{4(d+h)^2+s^2+4(d+h)s\sin\theta}}\right\} \quad ... (9)$$

$$\Psi_r = \Phi_r + \frac{Q^{/}}{4\pi\varepsilon_0}\left\{\frac{1}{2(d+s\sin\theta)} - \frac{1}{\sqrt{4d^2+s^2+4ds\sin\theta}}\right\} + \frac{Q^{//}}{4\pi\varepsilon_0}\left\{\frac{1}{2(d+h+s\sin\theta)} - \frac{1}{\sqrt{4(d+h)^2+s^2+4(d+h)s\sin\theta}}\right\} \quad ... (10)$$

The potential variation ΔV at the sensor electrode (i.e., at point charge Q_0) due to image charges at each layer of materials was calculated by using equations 3 and 4, i. e.,

$$\Delta V_{tr} = (\Psi_t - \Psi_r) - (\Phi_t - \Phi_r) \quad ... (11)$$

Using suitable approximation as used in research paper in reference [4],

$$\frac{1}{2d} + \frac{1}{2(d+s\sin\theta)} - \frac{1}{\sqrt{4d^2+s^2+4ds\sin\theta}} \cong \frac{s^2}{8d^3}(Sin^2\theta+1)$$

it can be shown that,

$$\Delta V_{tr} = \frac{-Q^{/}}{4\pi\varepsilon_0}\left[\frac{s^2(Sin^2\theta+1)}{8d^3}\right] - \frac{Q^{//}}{4\pi\varepsilon_0}\left[\frac{s^2(Sin^2\theta+1)}{8(d+h)^3}\right]$$

$$\Delta V_{tr} = \left[\frac{1}{(\varepsilon_0+\varepsilon_1)}\right]\left\{\frac{(\varepsilon_0-\varepsilon_1)}{d^3} + \frac{2\varepsilon_1(\varepsilon_1-\varepsilon_2)}{(d+h)^3(\varepsilon_1+\varepsilon_2)}\right\}(Sin^2\theta+1) \quad ... (12)$$

According to the equation for capacitance,

$$Q = CV$$

$$\frac{\Delta C_{tr}}{C_{tr}} = \frac{\Delta V_{tr}}{V_{tr}} = \frac{\Delta V_{tr}}{Q/C_{tr}}$$

$$\frac{\Delta C_{tr}}{C_{tr}^2} = \frac{\Delta V_{tr}}{Q} \quad ... (13)$$

where,

ΔV_{tr}= Potential variation

V_{tr} = Potential variation between the electrodes

ΔC_{tr}= Capacitance variation

C_{tr}= Capacitance between the electrodes

Then by using equation 13 and the transformed relationship for mirror image charges Q/ and Q//(2.1 and 2.2), it is shown that the variation of capacitance ΔC is given by the following function (equation 14)

$$\Delta C_{tr} = \frac{-S^2C_{tr}^2}{32\pi\varepsilon_0}\left[\frac{1}{(\varepsilon_0+\varepsilon_1)}\right]\left\{\frac{(\varepsilon_0-\varepsilon_1)}{d^3} + \frac{2\varepsilon_1(\varepsilon_1-\varepsilon_2)}{(d+h)^3(\varepsilon_1+\varepsilon_2)}\right\}(Sin^2\theta+1)$$

$$\Delta C = \frac{-C^2S^2}{32\pi\varepsilon_0}\left[\frac{1}{(\varepsilon_0+\varepsilon_1)}\right]\left\{\frac{(\varepsilon_0-\varepsilon_1)}{d^3} + \frac{2\varepsilon_1(\varepsilon_1-\varepsilon_2)}{(d+h)^3(\varepsilon_1+\varepsilon_2)}\right\}(Sin^2\theta+1) \quad ... (14)$$

where,
ε_0 - Dielectric constant of the free space
ε_1 - Dielectric constant of the first layer material
ε_2 - Dielectric constant of the second layer material
s - Separation of the electrodes
d - Shortest distance between the electrode and the object
h - Thickness of the first layer of material
C- Capacitance of the sensor electrode without object

5. Testing and Implementation

5.1 Simulation for the Developed Model

The theoretically derived function (equation 08) was simulated using MATLAB® software and relevant plots were obtained for the cases of a, b and c and observations were analyzed for getting useful data required for the design.

a. When the first and second layers are nonmetallic materials

In this case, various plots were obtained for capacitance variation ratio vs. thickness of the first layer materials, for the various first layer materials such as rubber, wood, glass, ceramic and paper by keeping second layer material fixed for plastic and vice versa.

i. Plots for ΔC for the deferent first layer materials (Figure 9) have considerable deviations from each other when the 1st layer materials have considerably different dielectric constant values (ε_1).

ii. Plots for ΔC for the deferent second layer materials (Figure 10) have considerable deviations with each other when the 2nd layer materials have considerably different dielectric constant values (ε_2).

iii. For both cases when $\varepsilon_1 > \varepsilon_2$, ΔC values are increasing(nearly up to 10 mm of1st layer thickness) and reaches a constant value. When$\varepsilon_1 < \varepsilon_2$, ΔC values are decreasing (nearly up to 10 mm of 1st layer thickness) and goes to a constant value.

b. When the first layer is metallic and second layer is nonmetallic

When the first layer is metallic $\epsilon_1 \rightarrow \infty$ and equation for ΔC becomes,

$$\Delta C = \frac{C^2S^2}{32\pi\varepsilon_0}\left\{\frac{1}{d^3}-\frac{2}{(d+h)^3}\right\}(Sin^2\theta+1) \qquad \text{... (15)}$$

In this case various plots were obtained for capacitance variation ratio vs. thickness of the first layer metallic material, for various second layer non-metallic materials such as rubber, wood, glass, ceramic and paper.

Here, it was observed (Figure 3) that ΔC is increasing and goes to a constant and it does not depend on first- and second-layer dielectric constants, but it depends on lower (nearly up to 10 mm) values of 1st layer thickness.

c. When the first layer is non-metallic and the second layer is metallic

When the second layer is metallic $\epsilon_2 \rightarrow \infty$ and equation for ΔC becomes,

$$\Delta C = \frac{-C^2S^2}{32\pi\varepsilon_0}\left[\frac{1}{(\varepsilon_0+\varepsilon_1)}\right]\left\{\frac{(\varepsilon_0-\varepsilon_1)}{d^3}-\frac{2\varepsilon_1}{(d+h)^3}\right\}(Sin^2\theta+1) \qquad \text{... (16)}$$

In this case, various plots were obtained for capacitance variation ratio vs. thickness of the first layer materials, for various first layer non-metallic materials such as rubber, wood, glass, ceramic and paper by keeping second layer fixed (any metallic material).

Here, it was observed (Figure 4) that ΔC is decreasing and goes to a constant and it does not depend on second layer dielectric constant but it depends on the first layer dielectric constant and on lower (nearly up to 10 mm) values of 1st layer thickness.

Plots for ΔC for the deferent first layer materials have considerable deviations with each other when the 1st layer materials have considerably different dielectric constant values (ε_1).

5.2 Experiment for the Calibration of the Sensor

This experiment was carried out to find a suitable variable which can be used for the calibration of the sensor by considering the RC oscillation stage of the capacitive proximity sensor.

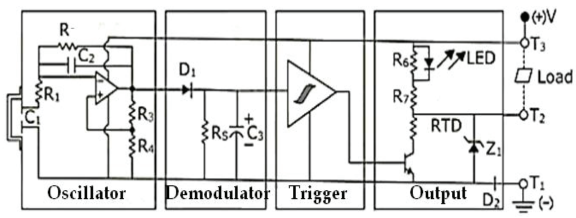


Figure 4 - Functional stages of the capacitive proximity sensor (omchsmps.com)

Due to variations of the sensor head capacitance values when the materials are sensing, the oscillation frequency of the RC oscillator circuit which is connected to the sensor head capacitor (Figure 4) will change. As a result, to get the desired oscillations for the material detection, it is required to adjust the resistance value (R) of the RC oscillator until it gives a transistor output. By observing that the values of R required to obtain desired oscillations were deferent for each material, the sensor was calibrated using R values with respect to the different material samples (to prevent arising external effect in the sensor circuit functionality voltage (V) across the POT could not be used).

LJC18A3-H-Z/BY type capacitive proximity sensor was used for this experiment. The resistance and the voltage across the potentiometer (of the sensor RC circuit) which were required to adjust desired oscillations for detecting materials were measured as in Tables 1, 2 and 3 for the deferent cases (a, b and c) using a setup as shown in Figure 5.

a. By varying the thickness of different types of single layer materials for 1 mm sensing distance.
b. By varying the thickness of different types of single layer materials for 15 mm sensing distance.

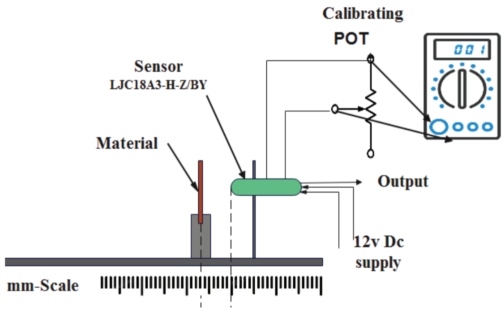


Figure 5 - Apparatus setup used for the experiment

c. By varying the thickness of different types of second layer materials and keeping the first layer material constant for two layers of materials for 1mm sensing distance.

Table 1 - Resistance and voltage readings across the POT for the case-a

Materials at 1mm sensing distance	Potentiometer readings(Ω) for thickness				Voltage across POT. (mV) for thickness			
	2mm	5mm	10mm	20mm	2mm	5mm	10mm	20mm
Aluminum	412.0	431.0	496.0	502.0	107.5	111.9	128.1	133.6
Wood	254.0	270.0	314.0	320.4	66.6	70.2	90.8	94.4
Glass	227.0	276.0	276.0	278.0	60.3	72.7	84.7	90.3
Cardboard	192.8	245.0	275.0	282.0	49.0	64.8	72.6	78.5
Rubber	139.1	155.3	156.3	158.2	36.8	41.2	41.8	42.4
Plastic	161.5	199.0	214.0	217.1	42.6	52.8	59.3	62.0

Table 2 - Resistance and voltage readings across the POT for the case-b

Materials at 15mm sensing distance	Potentiometer readings(Ω) for thickness				Voltage across POT. (mV) for thickness			
	2mm	5mm	10mm	20mm	2mm	5mm	10mm	20mm
Aluminum	150.0	150.6	153.0	154.0	40.0	40.3	40.7	40.9
Wood	132.4	139.3	142.6	144.2	34.3	37.2	37.6	37.6
Glass	135.5	152.5	153.3	154.3	36.1	40.5	41.0	41.8
Cardboard	144.7	147.8	151.1	152.0	38.3	39.5	40.6	40.8
Rubber	132.2	134.8	142.6	148.5	35.2	36.1	37.8	38.0
Plastic	132.2	135.0	142.6	148.2	35.2	36.1	38.0	38.6

Table 3 - Resistance and voltage readings across the POT for the case-c

Materials at 1mm sensing distance	Potentiometer readings(Ω) for thickness				Voltage across POT. (mV) for thickness			
	2mm	5mm	10mm	20mm	2mm	5mm	10mm	20mm
Plastic - Aluminums	283.0	313.0	320.0	322.0	74.6	82.5	84.6	85.2
Plastic - Wood	237.0	238.0	252.0	252.0	62.4	63.2	68.0	69.4
Plastic - Glass	182.1	227.0	237.0	238.0	48.1	59.0	62.9	63.5
Plastic - Cardboard	208.0	234.0	237.0	237.0	55.2	62.0	62.9	63.6
Plastic - Rubber	164.1	173.1	182.3	18.5	44.2	45.6	53.0	56.2

5.3 Hardware Design and Software Programming

For the hardware implementation, an ATmega328p microcontroller was used as the main microcontroller and a LJC18A3-H-Z/BY type capacitive proximity sensor for the detection of different materials, an Ultrasonic sensor (HC-SR04) for obstacle detection, a Bluetooth module (HC-05) to enable wireless communication, a digitally controlled potentiometer (X9C103) instead of inbuilt POT to adjust the resistance value for obtaining desired oscillations at material detection.

Voltage regulators (LM7805), a buzzer, LEDs, Resistors and two Lithium Polymer power sources were selected and fabricated according to Figure 6.

An algorithm was developed for controlling sensors and other modules for taking input signals from them and processing them for controlling output devices to make required outputs. Set of C++ programme codes written in Arduino IDE were used to programme the ATmega 328 p microcontroller.

5.3.1 Block diagram for the design

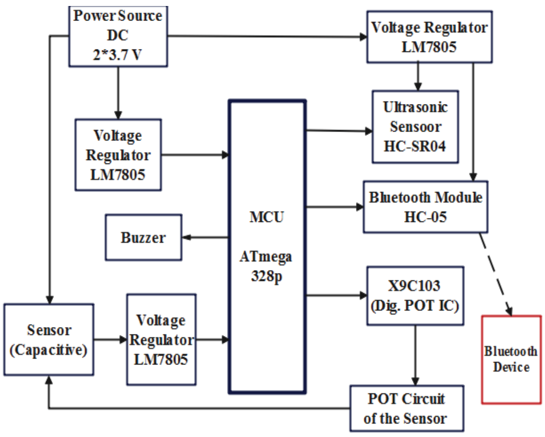


Figure 5 - Block diagram for the PCB design

5.3.2 Fabrications of hardware

Top view of the PCB is shown in Figure 6, actual view in Figure 7 and actual view of the device in Figure 8.

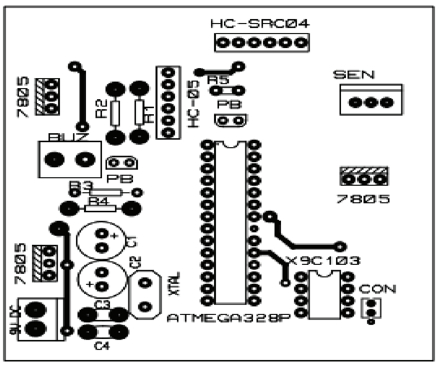


Figure 6 - Top view of the PCB

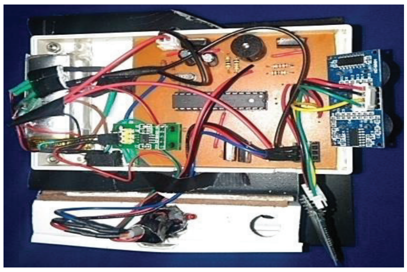


Figure 7 - Actual view of the PCB

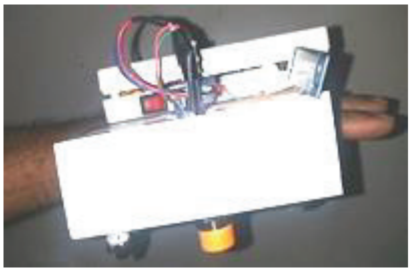


Figure 8 - Actual view of the device

5.4 Expected features of the design

The developed device is wearable box shape and 13cmx11.5cmx 6.5cm in dimensions and 285g weight.

- Low-cost device.
- Can be used as an obstacle detection component to get personal safety.
- Helps the blind people to detect materials such as metal, wood and glasses.
- Emit voice signals wirelessly to be aware of the material which are touching.

6. Results

6.1 Results for the Derivation of the Equation

The derived mathematical equation for the ΔC for two layers of material case for capacitive proximity sensing was,

$$\Delta C = \frac{-C^2 s^2}{32\pi\varepsilon_0}\left(\frac{1}{\varepsilon_0+\varepsilon_1}\right)\left\{\frac{\varepsilon_0-\varepsilon_1}{d^3} + \frac{2\varepsilon_1(\varepsilon_1-\varepsilon_2)}{(d+h)^3(\varepsilon_1+\varepsilon_2)}\right\}(\sin^2\theta+1)$$

(A suitable approximation at the derivation is used to simplify the complex equation.)

6.2 Results for the Simulation of the Equation

Results obtained by simulating equation 08 for ΔC by using MATLAB® are,

a. When both layers are non-metallic

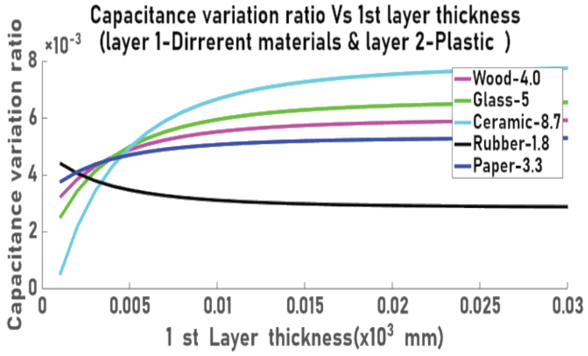


Figure 9 - Variation of capacitance with 1st layer material thickness for different 1st layer non-metallic materials(both layers are non-metallic).

Δ depends on 1st layer dielectric constant (Figure 9).

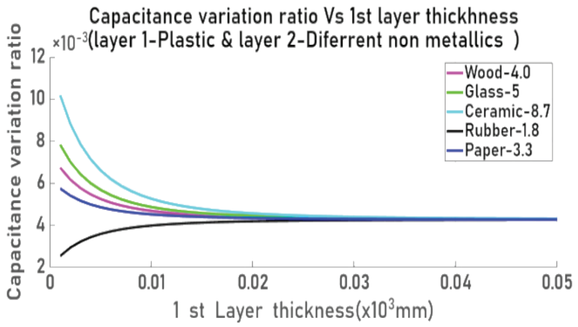


Figure 10 - Variation of capacitance with 1st layer material thickness for different 2nd layer non-metallic materials (both layers are non-metallic)

ΔC Depends on 2nd layer dielectric constant (Figure 10) for lower values (nearly up to 10 mm) of 1st layer thickness.

b. When the first layer is metallic and second layer is nonmetallic

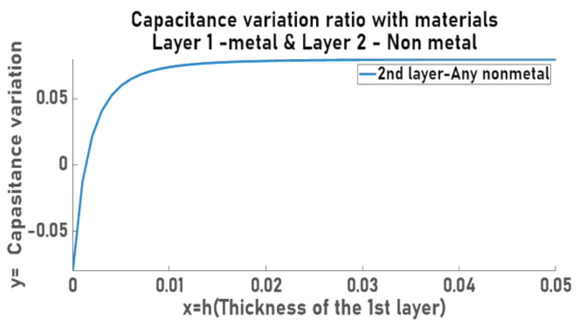


Figure 11 - Variation of capacitance with 1st layer material thickness for 1st layer metallic and2nd layer different non-metallic materials.

ΔCdoes not depend on first and second-layer dielectric constants (Figure 11).

c. When the first layer is non-metallic and the second layer is metallic

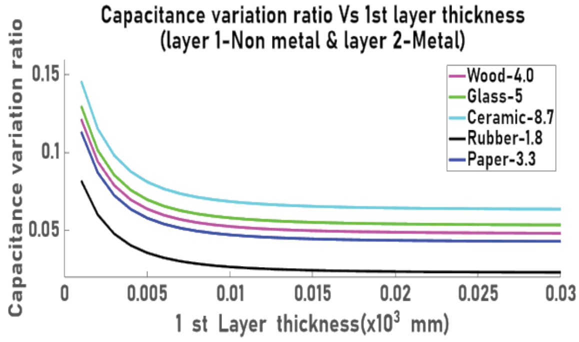
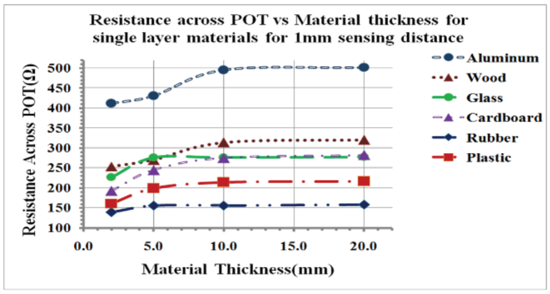


Figure 12 - Variation of capacitance with 1st layer material thickness for 1st layer different non-metallic and 2nd layer metallic materials

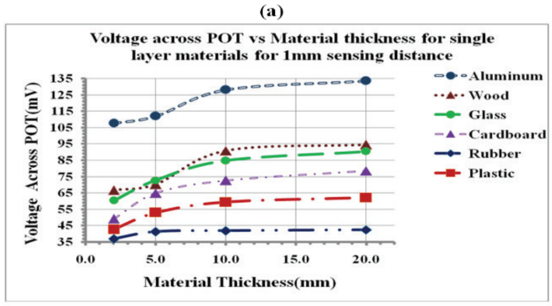
ΔC does not depend on the second layer dielectric constant but it depends on the first layer dielectric constant.

6.3 Results for the Experiment on Calibration of the Sensor

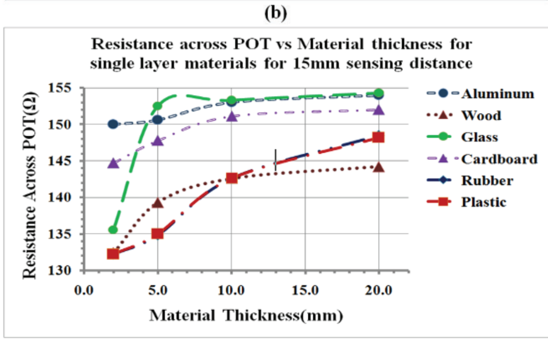
According to the data obtained through the experiment (Section 5.2) for cases a, b and c different types of plots as shown in Figure 13 a, b, c, d, e and f were obtained.



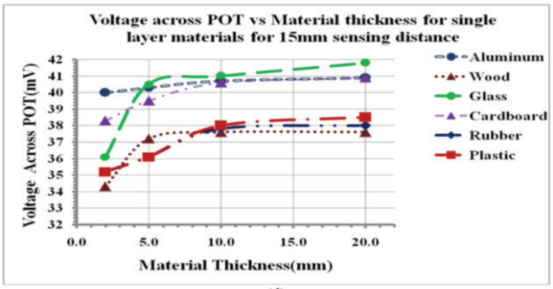
(a)



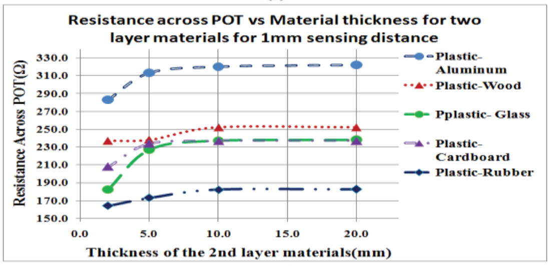
(b)



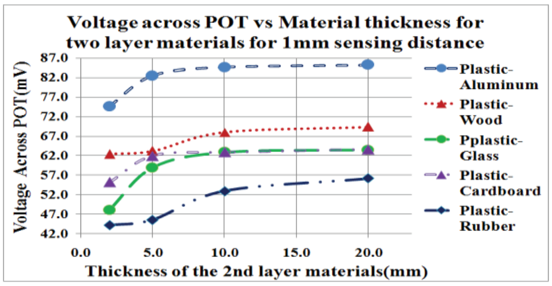
(c)



(d)



(e)



(f)

Figure 13 a,b,c,d - Potentiometer values for single layer materials: e,f - Potentiometer values for two layer materials

6.4 Observations for the Experimental results

1. For the case of single layer materials (Figure 13 a, b, c, d), it was observed that plots for aluminum, glass, plastics, wood and rubber which have considerably different dielectric constant values (ε_1) were deviated to each other. However, the deviations of the plots for glass, cardboard and wood were not considerable.
2. For the case of two-layer materials (Figure 13 e and f) with fixed type of first layer material the plots were deviated.

It was observed that the plots for the plastic-aluminum, plastics-wood and plastic-rubber were deviated from each other; that means plots were deviated when 2nd layer dielectric constant values (ε_2) are considerably different.

3. According to the plots in Figure 13 a, b, c, d, e and f it was observed that,

   i. $\Delta C \propto$V variations of resistance across the POT of the sensor RC circuit to obtain desired oscillations for detecting the material.

   ii. $\Delta C \propto$ V variations of voltage across the POT of the sensor RC circuit to obtain desired oscillations for detecting the material.

7. Discussion

Detection of variations of dielectric constant values can be used for the material detection successfully (but with limitations when moisture contents of the object surface, dryness of the object materials varying with the surrounding conditions) as it has concluded that the variation of capacitance of the capacitive proximity sensor is considerably affected due to the different dielectric constant values and thickness of the different types of materials for single and two layers of materials.

There was no deviation between simulation results and the experimental results which will verify the accuracy of the conclusions and the derived equation forΔC.

The number of materials which can be detected using this design depends on the sensitivity of the sensor and the step size of the digital potentiometer.

If it could be developed a capacitive proximity sensor with high sensitivity and having auto focusing ability, it will be a major advantage for the accuracy and higher range of detections of the device.

The designed glove can be used to identify materials such as glass, metals and wood. As the device consists of Bluetooth technology, a voice signal can be taken out from a separate Bluetooth device at a distance or through a head set without disturbing others.

8. Conclusions

According to the plots it was concluded that the variations of sensor capacitance is affected due to the dielectric constant of different types of materials and thickness of each material.

Resistance across the potentiometer of the sensor RC circuit can be used for the calibration of the sensor by considering the RC oscillation stage of the capacitive proximity sensor.

Measuring resistance or voltage across the potentiometer of RC oscillator circuit of the capacitive sensor can be used successfully instead of measuring variations of capacitance for the material detection.

Mechanical POT of the sensor can be replaced by digitally controlled POT for making use of PWM signals for operating the POT.

According to the observations for Figures 13 a and 13 b, it can be concluded that the single layer materials such as metal, wood (or glass), rubber and plastics can identify separately for any thickness value. However, it is hard to detect glass and cardboard separately using this sensor.

Future Development

This study was done using industrial capacitive proximity sensors which do not have high sensitivity, since there is no miniature size sensor with high sensitivity developed yet. For future development it is better to use more powerful sensors with auto focusing when there is a suitable development or either develop such a sensor with high sensitivity and then use it for this research.

The size, shape and weight should reduce to be more user-friendly manner by using miniature size sensor, SMD type electronic components for the PCB.

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