Faculty of Computers and Information Technology (FCIT)

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Wall Scanner Apparatus to Detect Objects inside Walls

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Declaration

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at University of Tabuk or other institutions

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APPROVAL FOR SUBMISSION

We certify that this project report entitled "Wall Scanner Apparatus to Detect Objects inside Walls"

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Acknowledgment

We dedicate this endeavour to our loved ones, who have stood by us through good times and bad, and who have taught us that any goal can be accomplished through hard work.

Abstract

This project addresses the detection of hidden object behind walls through the integration of two fundamental subsurface sensing techniques. The first technique involves measuring changes in electromagnetic field parameters caused by alterations in the medium's impedance, either internally or at the surface, when a magnetic field propagates. The second technique focuses on detecting changes in the receiver's input impedance prompted by shifts in the electromagnetic properties of the probed medium.

In addition to these techniques, various sensors employ alternative methods for object detection within walls. Acoustic sensors, for instance, utilize sound waves to identify variations in material density, offering a unique approach. Ground-penetrating radar sensors, on the other hand, use radio waves to analyze subsurface structures. These examples highlight the project's exploration of diverse sensing methodologies for effective object detection.

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1 Chapter 1: Introduction

1.1 Introduction

Detecting objects within walls is a critical aspect of construction and home improvement projects. This process involves locating concealed elements such as electrical wiring, plumbing pipes, or reinforcement bars within the structural components of walls. Accurate detection is essential for ensuring safety, preventing damage, and streamlining work processes. Technological advancements, including the development of stud finders and electromagnetic scanners, have significantly enhanced the detection process.

Understanding the specific requirements and limitations of detection tools is paramount for successful object identification. The significance of this capability extends beyond construction projects, impacting various fields such as civil engineering, geological surveying, geophysical logging, archaeology, forensics, and utility infrastructure building and operation.

In modern urban and rural settings, utility infrastructures are often buried for aesthetic reasons and to protect them from weather-related damage and mechanical effects. Examples of subsurface infrastructures include underground power lines, gas lines, phone landlines, fiber-optic cables, TV cables, water pipes, and sewage systems. Metal components within walls, like concrete reinforcement bars and bearing structures in high-rise buildings, also fall under the category of engineering-related buried objects.

It's crucial to acknowledge that certain procedures in construction projects, such as wall drilling or earthworks, may unintentionally harm buried objects. This could have serious repercussions, emphasizing the need for caution among laborers to avoid damaging hidden items. In specific scenarios, such as cable or pipeline installations, tie-in placements, or precise drilling through reinforcing bars within a wall, workers may intentionally need to locate and interact with buried objects.

Metal detectors play a pivotal role in this process, relying on the creation of a scanning alternating magnetic field to identify interruptions caused by metal objects. A typical metal detector comprises two antennas – a transmitter and a receiver – positioned to nullify the instrumentation signal in the absence of buried objects. The presence of buried objects disrupts this balance, triggering a response from the receiver.

1.2 Problem solution

Our solution revolves around the development of electronic circuits designed to scan objects within walls and trigger alarms upon detection. This project is further augmented by the integration of a web application. The web application plays a crucial role by presenting real-time data regarding the detection process, enabling users to make informed and prompt decisions when necessary. This combined hardware and software approach ensures a comprehensive and effective solution for object detection within wall structures.

1.3 Objectives

The project aims to detect objects of different materials inside walls with low-cost approach.

1.4 Scope

We use electromagnetic or acoustic circuits and sensors to measure the resulting reflections and detect objects inside the wall.

2 CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Since antiquated times, individuals have been residing in houses and having a good sense of reassurance and safeguarded in light of the fact that they are encased by four walls. One can act unreservedly in the event that he accepts he shouldn't be visible. That is the specific justification for why others are keen on attempting to check out at him through the wall. Is it moral to do as such? Is it legitimate? It depends.

History of spying traces all the way back to the earliest long periods of development, when public activity had recently started. Some individuals attempt to figure out what others wish to stow away. Over the entire course of time, the dream of seeing through walls has spurred individuals and government offices to put resources into fostering these abilities not exclusively to control individuals and to expand their power yet additionally to forestall wrongdoing and fear and to save lives.

Much as people and different creatures see through influxes of noticeable light that bob off items and afterwards strike our eyes' retinas, radar "sees" by conveying radio waves that bob off targets and return to the radar's beneficiaries. Yet, similarly as light can't go through strong articles in amounts enormous enough for the eye to recognize, it's difficult to construct radar that can enter walls alright to show what's going on behind. Presently, Lincoln Lab specialists have fabricated a framework that can see through walls from some distance away, giving an immediate image of the action on the opposite side [1].

- **Technology Overview**: Stud finders are designed to locate framing studs behind the wall surface. They come in various types, including magnetic, electronic, and radar-based models. The technology has evolved to include features like deep scanning, AC wire detection, and even laser leveling.
- **Recent Advancements**: The latest stud finders offer improved accuracy and ease of use. Some models now feature multiple sensors and displays that provide a full view of the stud's width, enhancing precision in detection[2]. Innovations also include the integration of smartphone apps that can assist in stud finding[2].
- **Top Models**: Recent reviews highlight several top-performing stud finders, such as the **Bosch GMS120 Digital Multi-Scanner** and the **Franklin Sensors ProSensor T13**, which are praised for their accuracy and user-friendly interfaces[1]. Other notable models include the **Zircon MultiScanner A200** and

the **Franklin Sensors ProSensor 710+**, which offer unique features like illuminated marking arrows and intuitive displays.

- **Consumer Preferences**: User reviews often emphasize the importance of a balance between advanced features and simplicity. Many prefer stud finders that are straightforward to operate but still provide reliable and detailed information about the location and size of studs.
- **Market Trends**: There's a growing demand for tools that combine multiple functions, such as stud finders with built-in levels or laser pointers. This trend reflects the DIY community's preference for versatile and multi-functional tools[2].
- **Challenges and Considerations**: One of the challenges in stud finder technology is ensuring consistent performance across different wall materials and conditions. Users should consider factors like wall thickness, the presence of metal or wiring, and the type of stud material when selecting a stud finder.

2.2 What is ultrasonic?

An ultrasonic transducer is a device used to change over another kind of energy into a ultrasonic vibration. There are a few fundamental sorts, grouped by the energy source and by the medium into which the waves are being created. Mechanical devices incorporate gas-driven, or pneumatic, transducers like whistles as well as fluid driven transducers like hydrodynamic oscillators and vibrating cutting edges. These devices, restricted to low ultrasonic frequencies, have various modern applications, including drying, ultrasonic cleaning, and infusion of fuel oil into burners. Electromechanical transducers are undeniably more flexible and incorporate piezoelectric and magneto strictive devices. A magneto strictive transducer utilizes a sort of attractive material wherein an applied swaying attractive field crushes the molecules of the material together, making an occasional change in the length of the material and in this way delivering a high-recurrence mechanical vibration. Magneto strictive transducers are utilized basically in the lower recurrence runs and are normal in ultrasonic cleaners and ultrasonic machining applications [5].

2.2.1 How does it work?

A short ultrasonic heartbeat is sent at the time 0, reflected by an item. The sensor gets this sign and converts it to an electric sign. The following heartbeat can be sent when the reverberation is disappeared. This time span is called cycle period. The suggest cycle period ought to be something like 50ms. On the off chance that a 10μs width trigger heartbeat is shipped off the sign pin, the Ultrasonic module will yield eight 40kHz ultrasonic sign and distinguish the reverberation back.

The deliberate distance is corresponding to the reverberation beat width and can be determined by the equation above. In the event that no obstruction is identified, the result pin will give a 38ms significant level sign [6].

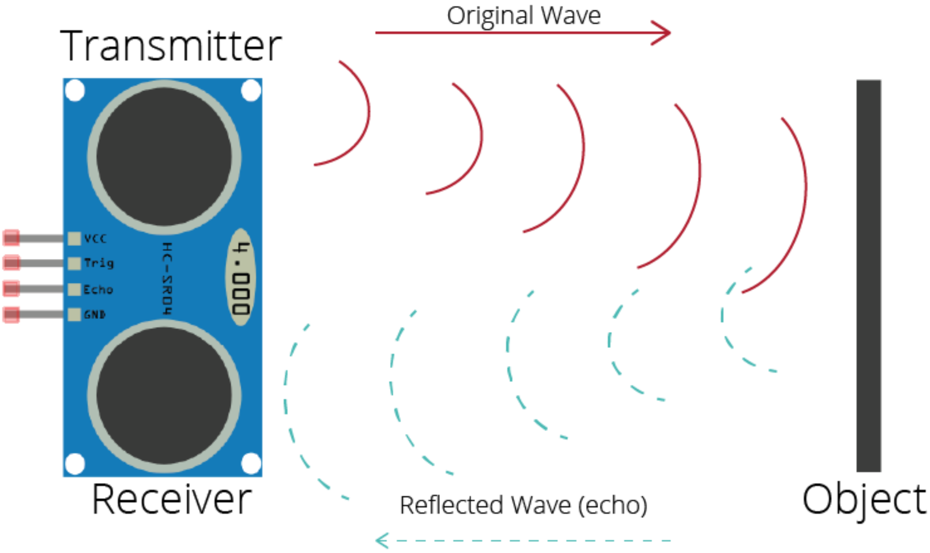

Figure 1 : Ultrasonic detection [7]

2.3 What is IR (Infrared)?

An infrared vicinity sensor or IR Sensor is an electronic device that emanates infrared lights to detect some part of the environmental factors and can be utilized to distinguish the movement of an article. As this is a detached sensor, it can quantify infrared radiation. This sensor is extremely normal in the electronic business and in the event that you've at any point attempted to plan an impediment aversion robot or some other vicinity discovery based framework, odds are you definitely have some familiarity with this module, and on the off chance that you don't, then follow this article as here we will examine every little thing about it [8].

2.3.1 How does it work?

The working of the IR sensor module is extremely basic, it comprises of two primary parts: the first is the IR transmitter segment and the second is the IR recipient area. In the transmitter segment, IR drove is utilized and in the collector area, a photodiode is utilized to get infrared sign and after some sign handling and molding, you will get the result [9].

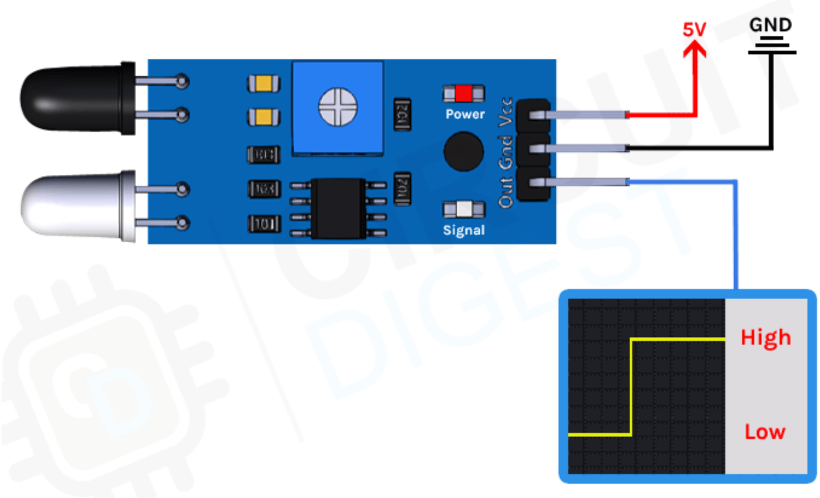

Figure 2 : IR detection [9]

2.4 *What is microwave?*

Closeness detecting is a typical application for interloper cautions, light switches, and other home and modern robotization applications. There are different techniques for closeness identification utilized in the gadgets business. The most widely recognized technique is to utilize the PIR sensor, which detects the adjustment of surrounding infrared radiation brought about by a warm body. Furthermore, other normal techniques include utilizing mirrored ultrasonic or light bars, in which the encroaching article mirrors the pillar back to its source where the time delay among transmission and gathering is estimated to ascertain the distance to the item [10].

2.4.1 How does it work?

The module has the qualities of high responsiveness, high enlistment distance, high dependability, enormous acceptance point, wide power supply voltage range, and so forth. It is broadly utilized in different sorts of human body acceptance lighting and caution, etc. This module upholds wide information voltage, going from 4 to 28V DC, and is furnished with RCWL-9196 chip RCWL with exceptionally negligible information accessible on the web. It has a responsiveness scope of ~7 meters. When set off, its TTL-level result (OUT) pin will change from LOW (0 V) to HIGH (3.3 V) for a limited time frame (2 to 3 s) prior to getting back to its inactive (LOW) state.

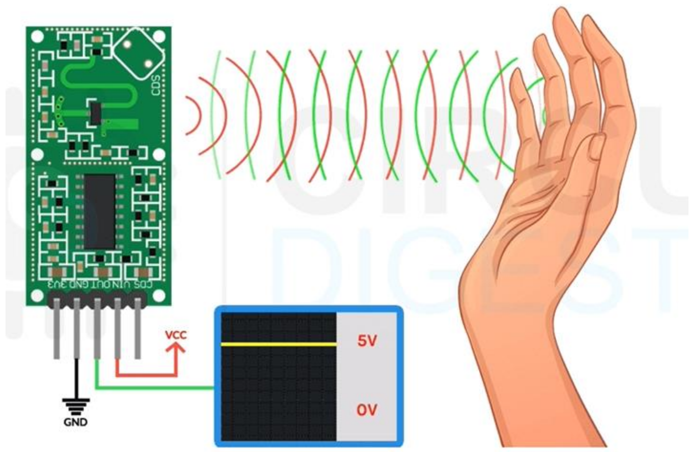

Figure 3 : Microwave [10]

2.5 *What is PIR motion sensor*

PIR sensors permit to detect movement. They are utilized to recognize whether a human has moved in or out of the sensor's reach. They are regularly found in apparatuses and contraptions utilized at home or for organizations. They are frequently alluded to as PIR, "Inactive Infrared", "Pyroelectric", or "IR movement" sensors [11].

2.5.1 How it works

It distinguishes infrared radiation from the climate. When there is infrared radiation from the human body molecule with temperature, zeroing in on the optical framework makes the pyroelectric gadget produce an unexpected electrical sign.

Essentially, when a human body or any creature cruises by, then it captures the main opening of the PIR sensor. This causes a positive differential change between the two cuts up. At the point when a human body leaves the detecting area, the sensor creates a negative differential change between the two cuts up [12].

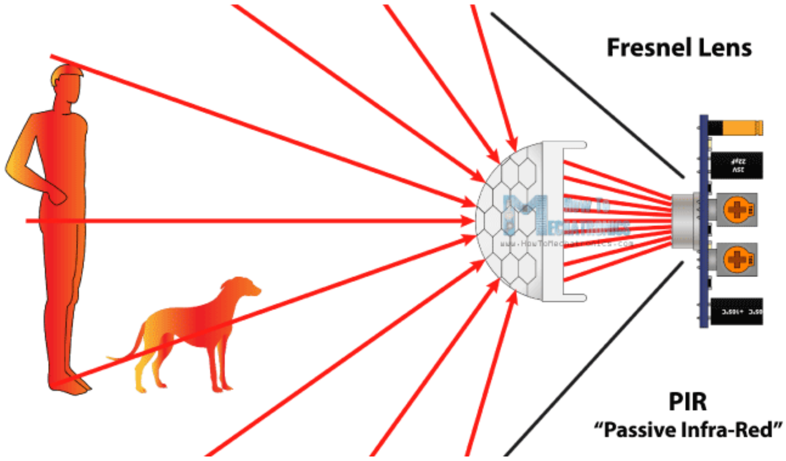

Figure 4 : PIR works [11]

2.6 Related works

In this section we demonstrate previous studies about detecting objects through radar systems:

2.6.1 Arduino Based Radar System for Short Range Applications

This study, is pointed toward planning a radar framework that utilizes an ultrasonic sensor to recognize objects. The ultrasonic sensor is utilized to quantify the distance between the radar and any item based non-contact innovation. This framework is controlled through Arduino. Arduino UNO board is gotten the job done to control ultrasonic sensor and furthermore to interact the sensor and show device. While, the development of the sensor is constrained by utilizing a little servo engine. This radar is controlled utilizing the Arduino Uno board as a microcontroller. The sign got from the sensor is handled utilizing "Handling Advancement Climate Programming". Super sonic sensor is joined to the servo engine it turns around 180 degree and gives visual portrayal on the product called handling IDE. Handling IDE gives graphical portrayal and it likewise gives point or position of the article and distance of the item. Catchphrases — Radar, Ultrasonic Sensor, Arduino Uno, Servo Engine [2].

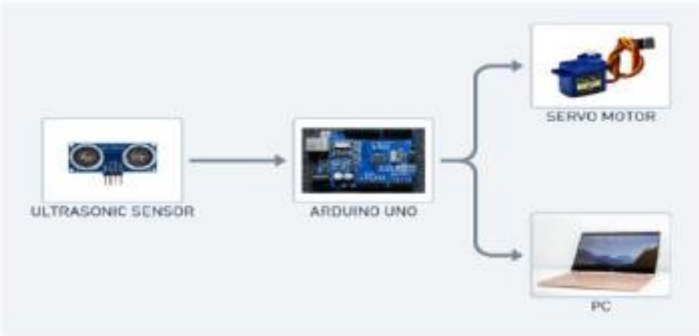

Figure 5 : Study 1 block diagram

2.6.2 Detection of Objects across the Walls with Wi-Fi Technology

The authors relay on Wi-Fi as a famous innovation that permits an electronic device to trade information or interface with the web remotely utilizing radio waves, Wi-Fi signals are normally data transporters between a transmitter and a beneficiary. Like a similar idea of Wi-Fi, Wi-Vi (WI-FI VISION) is another innovation that empowers seeing through walls utilizing Wi-Fi signals. It permits us to follow moving people through walls and away from public scrutiny. Wi-Vi depends on catching the impressions of its own communicated signals off moving objects behind a wall to follow them. Wi-Vi's activity doesn't expect admittance to any device on the opposite side of the wall. They demonstrate the way that Wi-Fi can likewise expand our faculties, empowering us to see moving items through walls and away from plain view. Specifically, they can utilize such motions toward recognize the quantity of individuals in a shut room and their relative areas. They can likewise recognize straightforward signals made behind a wall, and consolidate a grouping of signals to impart messages to a remote collector without conveying any sending device. The paper presents two principal developments. To start with, it demonstrates the way that one can utilize MIMO obstruction nulling to kill reflections off static items and spotlight the beneficiary on a moving objective [3].

Second, it demonstrates the way that one can follow a human by treating the movement of a human body as a receiving wire cluster also, following the subsequent RF bar.

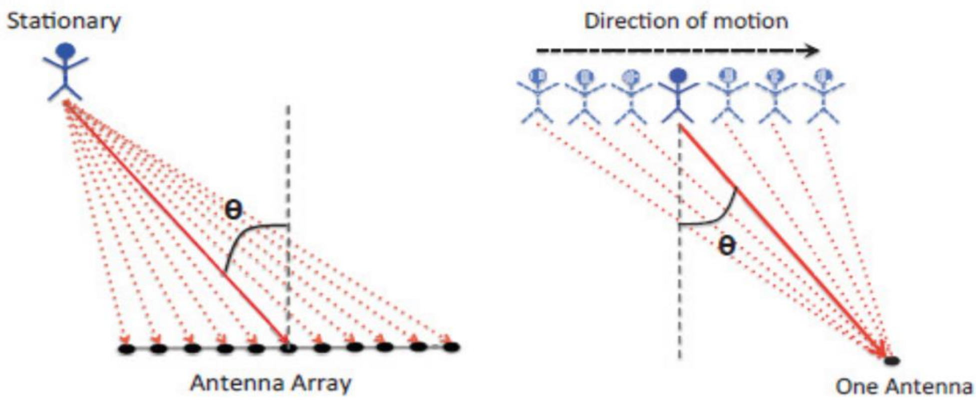

Figure 6 : Study 2 figure

2.6.3 Microwave Sensor with Arduino for humans and objects detection behind walls

The study involves this advanced Microwave Sensor with Arduino for moving people and articles recognition behind the walls. This computerized microwave Sensor utilizes Doppler radar to recognize moving items utilizing microwaves. This varies from the technique utilized by customary Infrared Sensor, Ultrasonic Sensor, PIR Sensor, TOF10120 sensor, and so on. He has involved these sensors in novices, moderate, and high level ventures. His is not saying these sensors are terrible however this microwave sensor is right at one more level as the microwaves are delicate to various items and the astonishing thing is its sensor readings are not impacted by encompassing temperatures. Thus, that is the reason, this kind of sensor is broadly utilized in modern, transportation, and common applications, for example, estimating fluid levels, programmed washing, estimating a vehicle's speed, programmed entryway movement detection, car switching, creation line material recognition, programmed lights control framework, significant level security frameworks, etc [4].

Figure 7 : Study 3 figure

2.7 Comparison

Item	General object detection	metal	wire	Plastic pipes	Control distance	cost
Bosch GMS120 Digital Multi-Scanner	–	✓	✓	–	✓	high
Franklin Sensors ProSensor T132	–	✓	✓	–	–	low
Franklin Sensors ProSensor 710+	–	✓	✓	–	–	low
Zircon Multi scanner A200	–	✓	✓	–	–	low
Our project	✓	✓	✓	✓	✓	low

3 Chapter 3: System Design

In this section, we've outlined key hardware components, such as sensors and processing units, as well as software requirements for object detection. It's important to note that these components, including sensors and the processing unit, can be easily modified or augmented to accommodate evolving project needs. The system's software can also be adapted or enhanced to integrate additional components, ensuring scalability and flexibility to meet future market demands and engineering expectations.

3.1 Hardware components

3.1.1 Arduino

Figure 8 : Arduino [13]

The Arduino microcontroller will be used in our project to process all project function. It is considered as the brain of our project. There are many types of Arduino microcontroller like UNO, LEONARDO 101, ESPLORA, MICRO, NANO, MINI, MKR2UNO, and ADAPTER. These are different on size, price, and performance.

Arduino **UNO** is the easiest and best board for the students and beginners of electronical projects and it is safe to use. The Arduino microcontroller is programmed by C++ language via Arduino IDE. The IDE is open source tool and cross platform it can be hosted on windows, linux, MAC, and other systems [13].

3.1.2 LCD screen

The project will use **LCD** monitor to display detection data.

Figure 9: LCD screen [14]

LCD screen has 16 columns and 2 rows. It is suitable to show information of detected objects. LCD with I2C board makes it easy to connect with Arduino with 4 wires only [14].

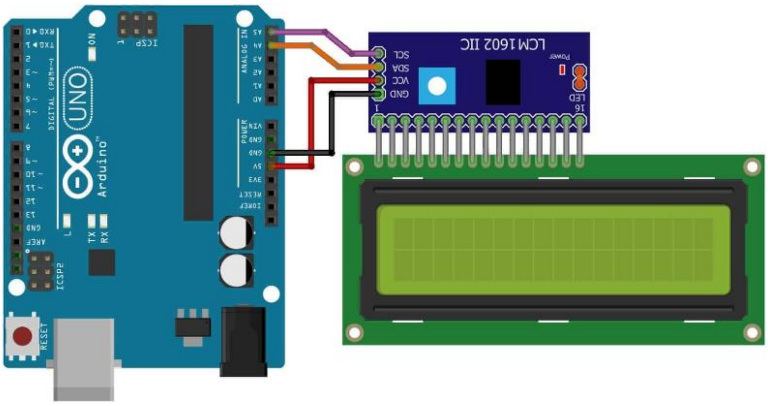

Figure 10: LCD I2C with Arduino [14]

3.1.3 Breadboard Jumpers & wires

We will design the circuit on white breadboard and normal jumpers to perform the project. In the design we do not need to use PCB board and soldered pins. The jumpers to connect modules to the Arduino board data and power.

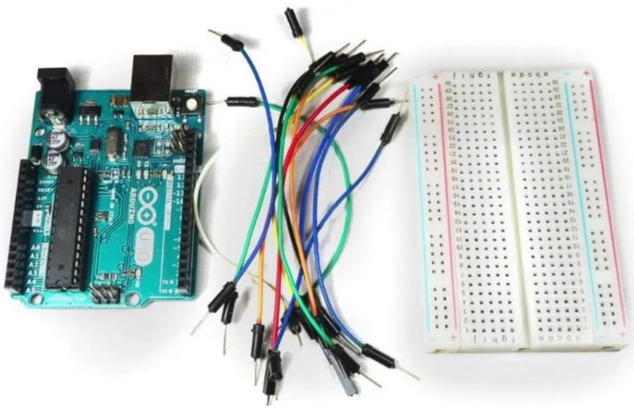

Figure 11 : Breadboard & jumpers [15]

3.1.4 Ultrasonic sensor (proposal)

This is the HC-SR04 ultrasonic distance sensor. This prudent sensor gives 2cm to 400cm of non-contact estimation usefulness with a running precision that can reach up to 3mm. Each HC-SR04 module incorporates a ultrasonic transmitter, a recipient and a control circuit [16].

Figure 12 : Ultrasonic [16]

3.1.5 RELAY MODULE

Figure 13 RELAY MODULE[17]

Relay:allow low-power microcontrollers to handle circuits that uses much higher power than what the board can handle directly. They are typically used in industrial applications to control high power circuits, but it is also used in cars, homes and other electric applications].

RCWL-0516 with Arduino connection

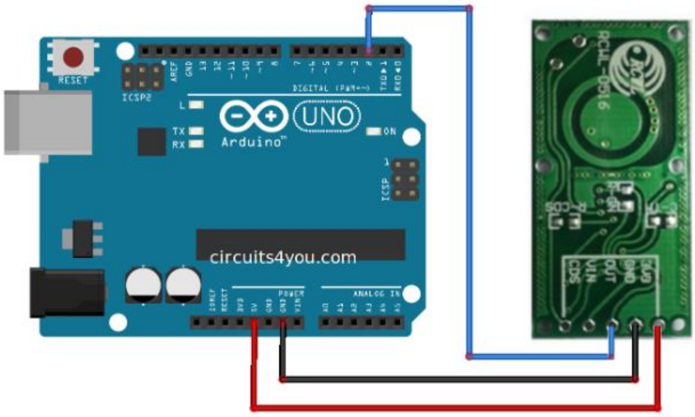

Figure 14 : Arduino with RCWL [17]

3.1.6 Buzzer

Buzzer connects with Arduino through a resistor with power and gnd pins [18].

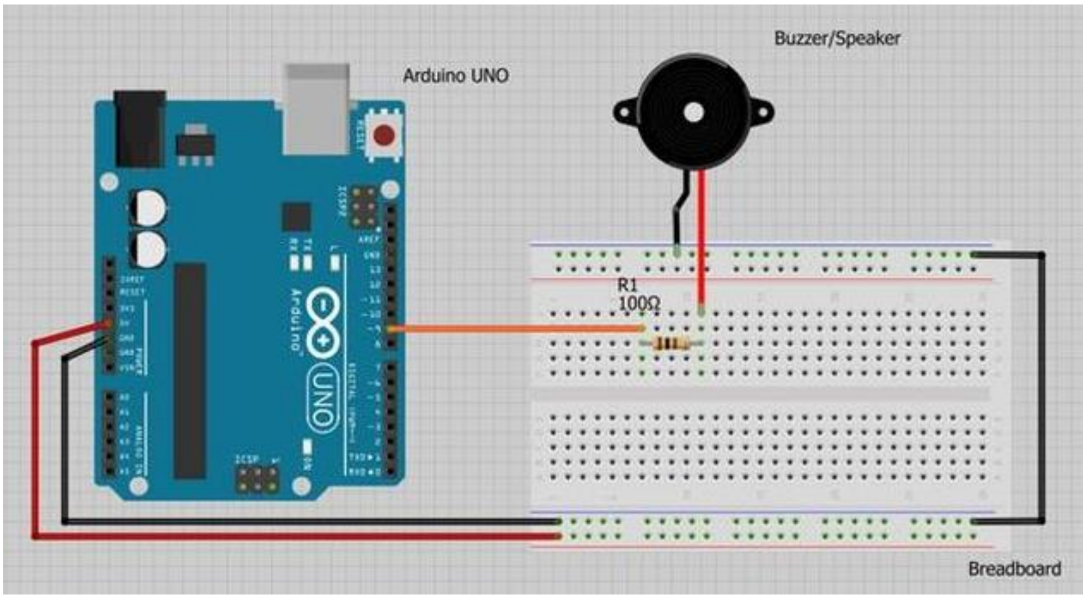

Figure 15 : Arduino Buzzer Cicuit [18]

3.2 Main Circuit

The figure below illustrates the complete sensor circuit integrated with Arduino to achieve the project's goals and objectives. It's important to note that the system is adaptable and open to modification or enhancement. Additional sensors or outputs, such as LEDs, can be easily incorporated, providing flexibility for future adjustments and improvements.

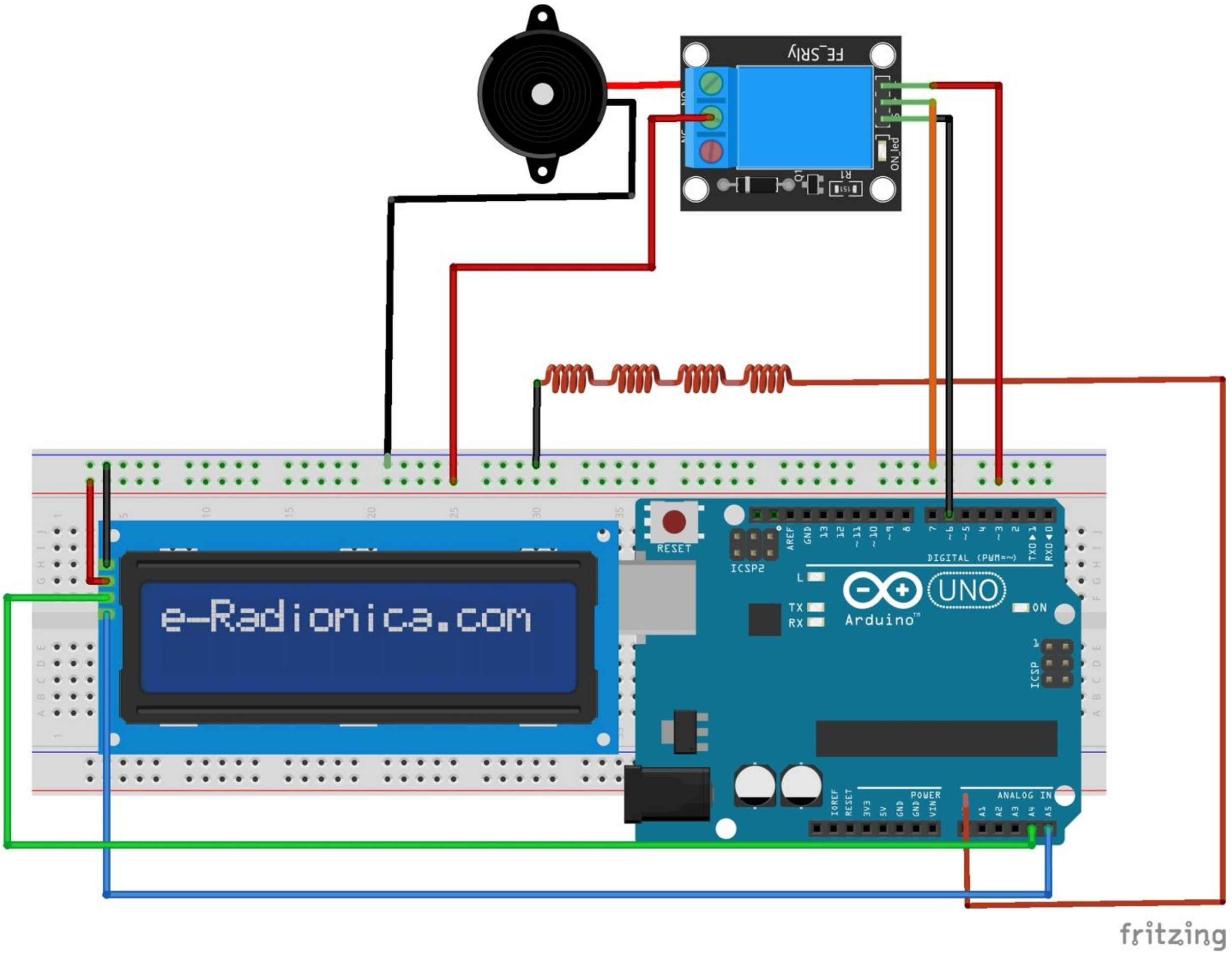

Figure 16 : main circuit

inductive proximity sensor :

An inductive proximity sensor is a type of non-contact electronic proximity sensor that is used to detect the position of metal objects. The sensing range of an inductive switch is dependent on the type of metal being detected.

3.3 *Flowchart*

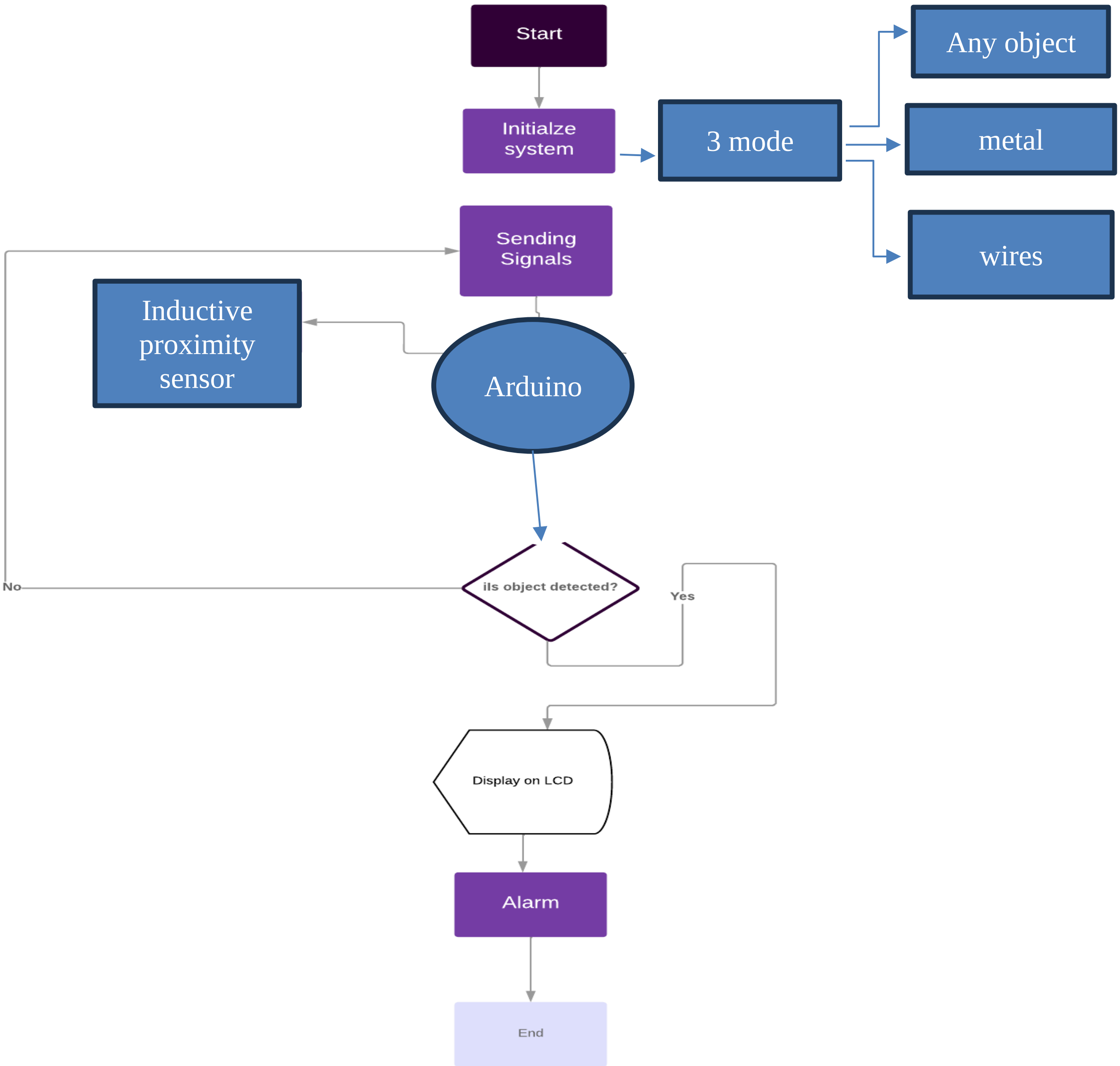

Figure 17 : Flowchart

3.4 Block Diagram

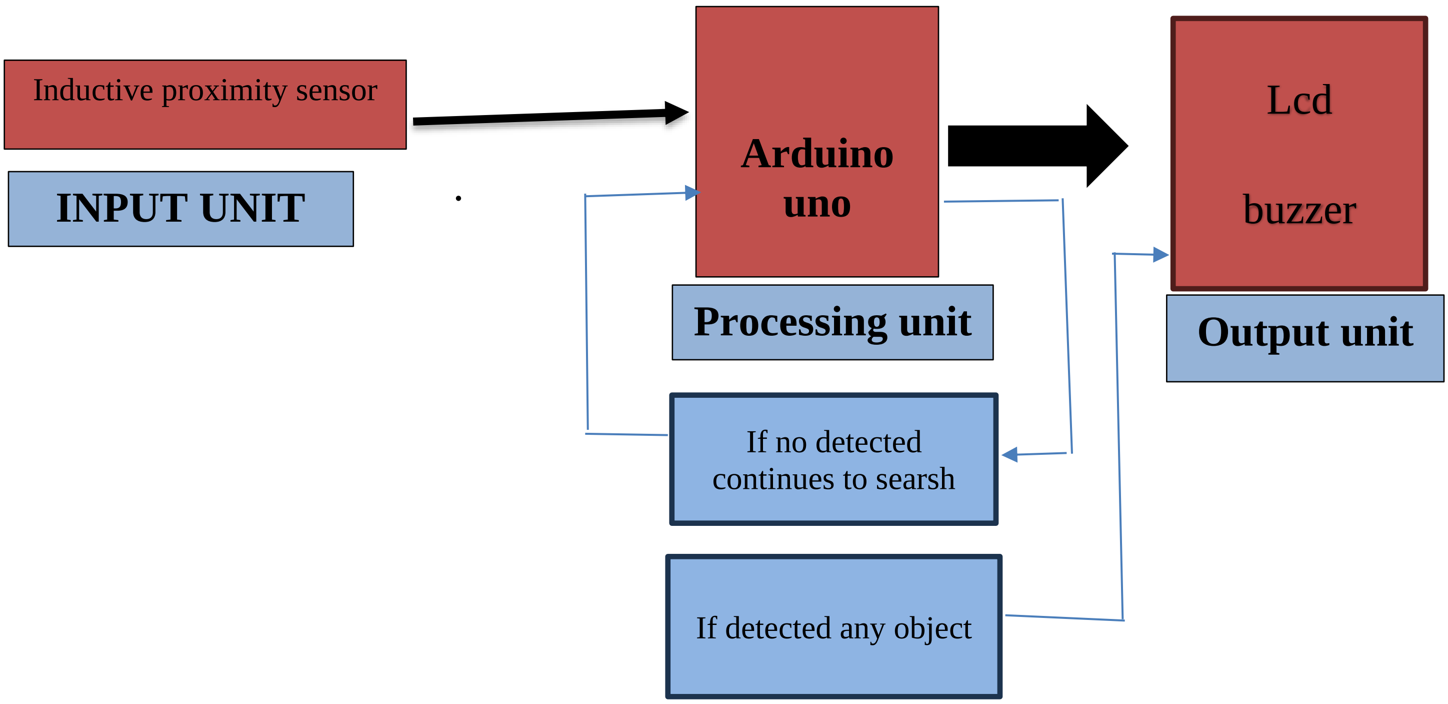

Figure 18 : Block Diagram

4 Manufacturing steps

4.1 *2 weekly working progress*

Week	Work
Week1	Distributing the work team to achieve a common union of interests, efforts, cooperation, and using the team members’ skills, talents, training, and experiences.
Week 2	Select the project and obtain approval from the responsible engineer.
Week 3	Determine the scope of the project and determine the roles of each individual in the work team.
Week 4	Search on Google Scholar for similar project ideas and collect the necessary information.
Week 5	Buy components
Week 6	Receive components and see hoe to connect it then make electric circuit diagram
Week 7	Start project programing
Week 8	Test the project
Week 9	Solve the problems then final test and make the project rebort
Week 10	Report discussion

4.2 *Manufacturing steps*

Table 1 working steps

week	work
Week 1	Buy components
Week 2	Draw circuit diagram for the peoject
Week 3	Receive components and see how to connect
Week 4	3d print and wood working to make the project body
Week 5	Connect the components together
Week 6	Start programming
Week 7	Test project
Week 8	The project lost
Week 9	Buying ll parts again and connect and program it
Week 10	Test the project , solve the problems , final test and make the project rebort

4.2.1 3d printing

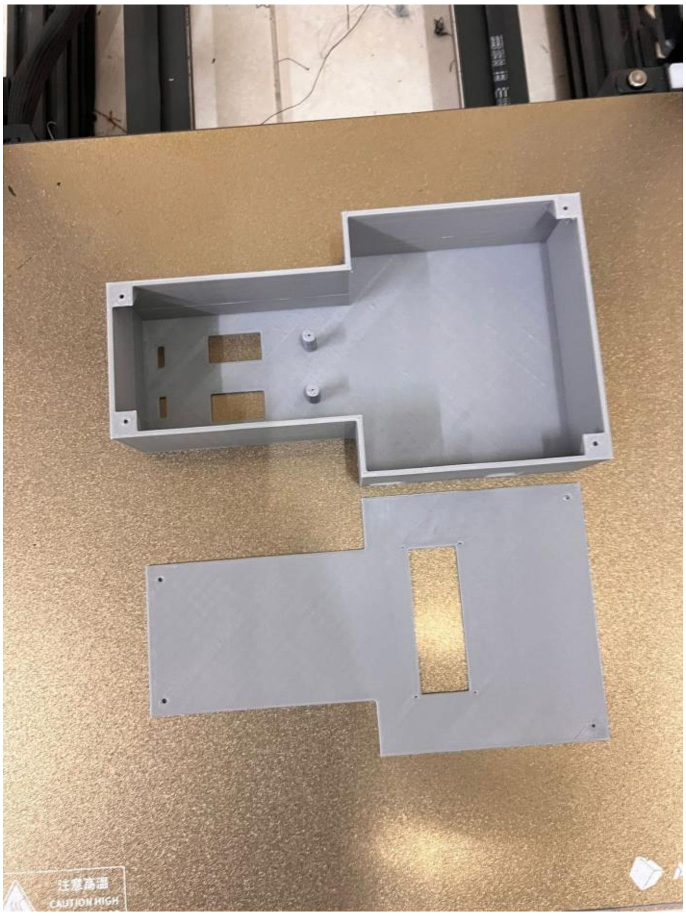

Figure 19 3d printing

4.2.2 Assembling parts

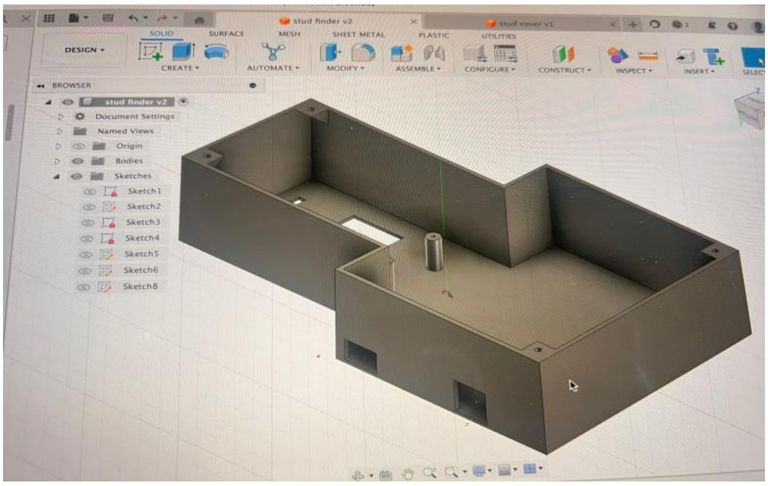

Figure 20 design

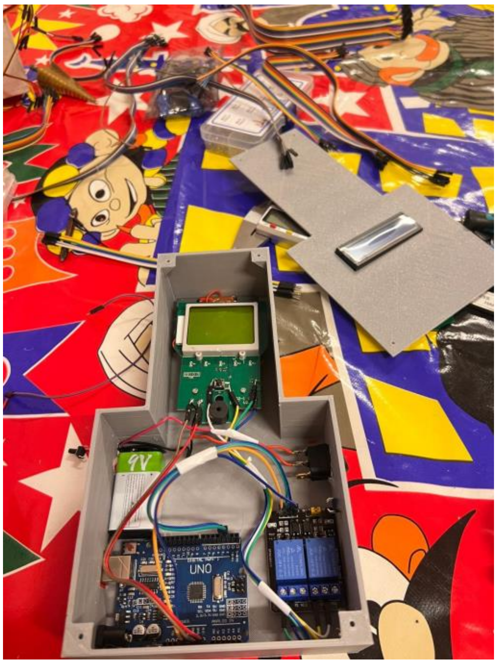

Figure 21 assembling

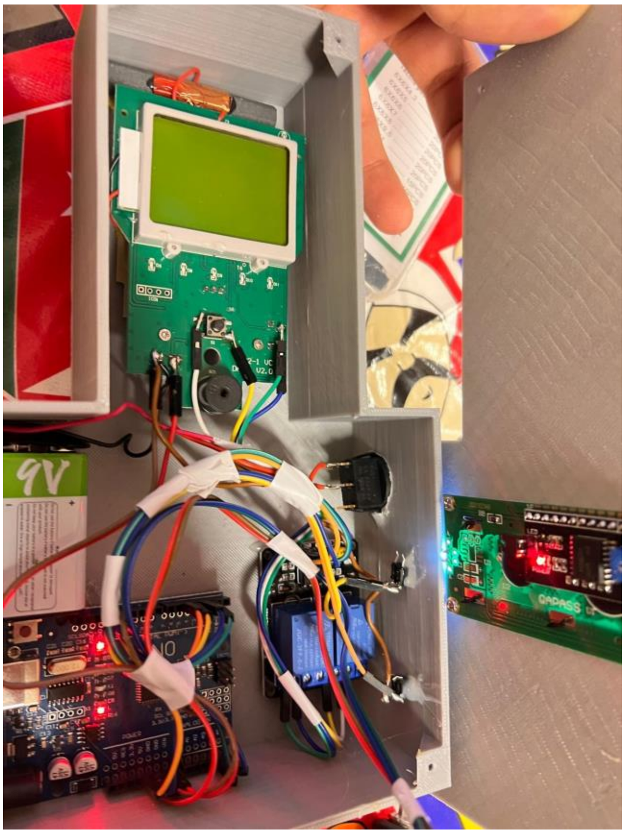

Figure 22 assembling

5 Conclusion

wall scanner with Arduino:

The wall scanner I've developed utilizes Arduino technology, incorporating an LCD screen, an inductive proximity sensor, a relay, and a push-button. When the sensor detects hidden objects such as metal, water pipes, or electrical wires within the walls, it sends signals to the Arduino board. The Arduino then processes these signals and activates the relay, triggering the push-button to emit a sound, alerting the user to the presence of detected objects. Additionally, the findings are displayed on the LCD screen, providing real-time feedback on the location and depth of the detected objects.

Benefits for Engineers:

Customizability: Engineers can tailor the device to suit specific project requirements by adjusting the Arduino code and integrating additional sensors or features as needed.
Cost-Effectiveness: Building a wall scanner using Arduino components is a cost-effective alternative to purchasing commercial devices, making it ideal for engineers working within budget constraints.
Educational Value: Developing a wall scanner using Arduino provides engineers with practical experience in electronics, programming, and sensor integration, enhancing their skills and knowledge.
Versatility: The ability to detect various materials such as metal, water pipes, and electrical wires makes the device versatile for engineers working on construction, renovation, or maintenance projects.
Efficiency: The real-time feedback provided by the LCD screen and audible alerts from the push-button streamline the scanning process, allowing engineers to quickly and accurately locate hidden objects behind walls, saving time and effort in project execution.

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7 Appendix 1

7.1 Porject Code

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27, 20, 4);  // set the LCD address to 0x27 for a 16 chars and 2 line display


int mode = 5;
int mod = 0;
boolean onn = 1;
int relay_mode = 3;
int calibrate = 4;

int relay_calibrate = 2;
void setup() {

  Serial.begin(9600);
  lcd.init();  // initialize the lcd
  lcd.init();
  lcd.backlight();
  lcd.setCursor(0, 0);
  lcd.print("GRADUATION PROJECT");
  lcd.setCursor(2, 1);
  lcd.print("wall scanner");


  pinMode(mode, INPUT_PULLUP);
  pinMode(calibrate, INPUT_PULLUP);


  pinMode(relay_mode, OUTPUT);
```

```
  pinMode(relay_calibrate, OUTPUT);

  digitalWrite(relay_calibrate, 1);
  digitalWrite(relay_mode, 1);
}


void loop() {


  if (digitalRead(calibrate) == 0) {

    digitalWrite(relay_calibrate, 0);
    delay(400);
    digitalWrite(relay_calibrate, 1);
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("calibrating");
    for (int i = 0; i < 16; i++) {
      lcd.setCursor(i, 1);
      lcd.print(">");
      delay(230);
    }
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("done calibrating");
    delay(1000);
  }




  if (digitalRead(mode) == 0 && onn == 1) {
    mod++;
```

```
  Serial.println(mod);
  onn = 0;
}
if (mod == 1 && onn == 0) {
  digitalWrite(relay_mode, 0);
  delay(400);
  digitalWrite(relay_mode, 1);


  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("put on the wall");
  lcd.setCursor(0, 1);
  lcd.print("to  calibrate");
  delay(2000);
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("mode stud finder");
  lcd.setCursor(1, 1);
  lcd.print("distance 1.5cm");

  onn = 1;
}

if (mod == 2 && onn == 0) {
  digitalWrite(relay_mode, 0);
  delay(400);
  digitalWrite(relay_mode, 1);


  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("put on the wall");
  lcd.setCursor(0, 1);
```

```
  lcd.print("to  calibrate");
  delay(2000);
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("mode stud finder");
  lcd.setCursor(1, 1);
  lcd.print("distance 2.5cm");

  onn = 1;
}

if (mod == 3 && onn == 0) {
  digitalWrite(relay_mode, 0);
  delay(400);
  digitalWrite(relay_mode, 1);


  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("put on the wall");
  lcd.setCursor(0, 1);
  lcd.print("to  calibrate");
  delay(2000);
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("mode stud finder");
  lcd.setCursor(1, 1);
  lcd.print("distance 4 cm");
  onn = 1;
}

if (mod == 4 && onn == 0) {
  digitalWrite(relay_mode, 0);
```

```
  delay(400);
  digitalWrite(relay_mode, 1);


  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("put on metal");
  lcd.setCursor(0, 1);
  lcd.print("to  calibrate");
  delay(2000);
  lcd.clear();
  lcd.clear();
  lcd.setCursor(6, 0);
  lcd.print("mode ");
  lcd.setCursor(2, 1);
  lcd.print("metal detect");
  onn = 1;
}

if (mod == 5 && onn == 0) {
  digitalWrite(relay_mode, 0);
  delay(400);
  digitalWrite(relay_mode, 1);


  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("put on wall");
  lcd.setCursor(0, 1);
  lcd.print("to  calibrate");
  delay(2000);
  lcd.clear();
  lcd.clear();
  lcd.setCursor(6, 0);
```

```
    lcd.print("mode ");
    lcd.setCursor(2, 1);
    lcd.print("wire detect");
    onn = 1;
  }

  if (mod == 6 && onn == 0) {


    mod = 0;
    onn = 1;
  }
}
```