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By: Lasmar Hanane

Theme

Smart Device to Guide Individuals to Wells in the Desert, Monitor Health Status and Send Emergency Notifications

Publicly defended on : JUIN 01, 2025 in front of the jury composed of :

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

رَبِّ زِدْنِي عِلْمًا

صَدَقَ اللهُ العَظِيم

إهــــــداء

بسم الله الرحمن الرحيم، والصلاة والسلام على أشرف الأنبياء والمرسلين.
في البداية، أحمد الله تعالى، أولاً وأخيراً، على فضله ورحمته. ما كنتُ لأنجح لولا فضله. الحمد لله في البداية والنهاية، الحمد لله كلما انتهى درب أو تحقق مسعى بفضله، الحمد لله على الإتمام وعلى فرحة الإنجاز.
مضت الأعوام، وتلاشى تعب الأيام، وها أنا أقف اليوم أمام حلمي بفخر، أحتفل بإنجازي واعتزازي بما وصلت إليه. بكل محبتي، أهدي هذا التخرج لكل من سعى معي لإكمال هذه الرحلة، دمتم سندي الدائم.
أهدي هذا التخرج إلى من ربتني وعلمتني القيم والمبادئ، إلى من كانت سندي وقوتي في الشدائد، أمي الحبيبة -أطال الله في عمرها- التي أنارت لي طريقي في أحلك الليالي لأحقق طموحاتي وأرتفع إلى أعلى المراتب، التي سهرت ودعمت وكافحت بلا كلل من أجل أن تراني متزيناً بشرف التخرج.
إلى من كان قدوتي ومثالي، والذي علمني الصبر والقوة، والدي العزيز، أهدي إليك هذا التخرج، داعياً الله أن يطيل في عمرك ويبقيك دائماً بجانبي.
إلى عمي الحبيب المرحوم الذي كان روحي وسندي وكان لي أخاً وصديقاً في كل لحظاتي أهدي إليك هذا التخرج سائلةً الله أن يتغمده بواسع رحمته وأن يجعل هذا العمل صدقة جارية له.
إلى إخوتي الأعزاء، أهدي هذا التخرج لمن كانوا عونًا لي وسندًا في كل خطوة. أنتم ملاذي الآمن و قلوبكم الوفيّة ساندتني و دعمتني بحبٍّ لا حدود له. أنرتم طريقي بتشجيعكم الدائم، وكل نجاح حققته يحمل بصمة دعمكم . أنتم مصدر إلهامي و قوتي؛ بحبكم ودعمكم اللامحدود، استطعتُ تجاوز التحديات. كانت ضحكاتكم نورًا أضاء أيامي. دمتم إخوةً أفخر وأعتزّ بهم دائمًا.

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ها أنا ذا يا أصدقائي، قد بلغتُ اليوم الذي طال انتظاره، اليوم الذي ناضلتُ من أجله، اليوم الذي بكيتُ فيه انتظاراً. هذا هو اليوم الذي سأشق فيه طريقي نحو حياة جديدة - حياة لا ترحب إلا بالأقوياء، أولئك الذين يسعون جاهدين لتحقيق أحلامهم مثلي. لقد سلكتُ طريقاً طويلاً، طريقاً كافحتُ للوصول إليه، طريقاً ضحكتُ فيه وبكيتُ معكم، طريقاً تشاركنا فيه نضالنا، وشعرنا أحياناً أنها النهاية. ومع ذلك، وكما هي العادة، نزل علينا لطف الله، مُعزياً إيانا لننهض من جديد حتى بلغنا غايتنا. الحمد لله حمداً كثيراً، الحمد لله الذي جمعني بكم، الحمد لله الذي وحّد قلوبنا، والحمد لله على الأيام التي قضيناها معاً، بأفراحها وأحزانها. سأفتقد كل لحظة عشتها معكم، ممتناً لكل ذكرى جميلة تجمعنا، وأعتذر عن أي شيء بدر مني، عن أي كلمة جرحت أحداً منكم دون قصد. أسأل الله العلي القدير أن يحقق لنا جميع أمانينا ويرزقنا القوة لمواصلة هذه المسيرة والسير نحو أحلامنا وتحقيق أعلى أهدافنا.
السلام عليكم ورحمة الله وبركاته.

حنان

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Abstract

This work describes a smart tool to enhance safety in the Algerian Sahara. It combines GPS wayfinding, vital signs monitoring (heart rate, body temperature), and Thuraya satellite communication for urgent alerts in remote areas. The tool helps locate water, monitors wellness, provides automatic emergency alerts, and uses a solar rechargeable battery. Tested in desert-like conditions, its economic viability is confirmed through market analysis and cost estimates. The device offers a cheap, useful solution for desert explorers, workers, and travelers, with potential in other harsh environments.

Keywords: Algerian Sahara , Vital Signs Monitoring , Global Positioning System (GPS) , Satellite Communication , Emergency

ملخص

يُبرز هذا العمل جهازًا ذكيًا لتحسين سلامة المسافرين في الصحراء الجزائرية. يجمع بين نظام تحديد المواقع، مراقبة العلامات الحيوية (معدل ضربات القلب، درجة حرارة الجسم)، والاتصال عبر الثريا لتنبيهات الطوارئ. يساعد في تحديد مصادر المياه، متابعة الصحة بإشعارات تلقائية، ويعمل ببطارية شمسية. أثبت جدواه الاقتصادية عبر اختبارات صحراوية وتحليل السوق، مقدمًا حلاً عمليًا لمستكشفي الصحراء والمسافرين، مع تطبيقات في بيئات صعبة.

الكلمات المفتاحية: الصحراء الجزائرية ، مراقبة العلامات الحيوية ، نظام تحديد المواقع ، اتصال عبر الأقمار الصناعية ، طوارئ

Résumé

Ce travail présente un dispositif intelligent pour améliorer la sécurité des voyageurs dans le Sahara algérien. Il combine navigation GPS, suivi des signes vitaux (fréquence cardiaque, température du corps) et communication par satellite via Thuraya pour alertes en zones isolées. Il aide à trouver des sources d'eau, suivre la santé avec notifications automatiques d'urgence, et fonctionne sur énergie solaire. Testé en désert, il est économique avec analyse de marché et estimations de coûts. Il offre une solution bon marché pour explorateurs, travailleurs et voyageurs, avec applications possibles dans d'autres terrains difficiles.

Mots Clée : Sahara algérien , Surveillance des signes vitaux , Système de positionnement global (GPS) , Communication par satellite , Urgence.

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List of Acronyms

2D Two-Dimensional

3D Three-Dimensional

ADC Analog-to-Digital Converter

AI Artificial Intelligence

AMR Adaptive Multi-Rate

AR Augmented Reality

AT Attention

ATmega328P AVR 8-bit Microcontroller

AWG American Wire Gauge

BeiDou BeiDou Navigation Satellite System (China)

BPM Beats Per Minute

CEP Circular Error Probable

CSD Circuit-Switched Data

DC Direct Current

DRDY Data Ready

DSP Digital Signal Processor

EEPROM Electrically Erasable Programmable Read-Only Memory

EGNOS European Geostationary Navigation Overlay Service

FOV Field of View

FTP File Transfer Protocol

GLONASS Globalnaya Navigatsionnaya Sputnikovaya Sistema

GND Ground

GNSS Global Navigation Satellite System

GPI General Purpose Input

GPRS General Packet Radio Service

GPS Global Positioning System

GSM Global System for Mobile Communications

HMC5883L Honeywell Magneto-Compass 5883L

HTTP HyperText Transfer Protocol

I2C Inter-Integrated Circuit

ICSP In-Circuit Serial Programming

IDE Integrated Development Environment

IR Infrared

LCD Liquid Crystal Display

LED Light Emitting Diode

LEDs Light Emitting Diodes

LNA Low Noise Amplifier

MLX90614 Melexis 90614

MSAS MTSAT Satellite Augmentation System

NMEA National Marine Electronics Association

PCB Printed Circuit Board

Pi Raspberry Pi

PPG Photoplethysmography

PPP Point-to-Point Protocol

PWM Pulse Width Modulation

QZSS Quasi-Zenith Satellite System

ROM Read-Only Memory

RX Receive

SBAS Satellite-Based Augmentation System

SCL Serial Clock Line

SDA Serial Data Line

SIM Subscriber Identity Module

SIM900 SIMCom 900

SIMCOM SIMCom Wireless Solutions Ltd.

SMA SubMiniature version A

SMBus System Management Bus

SMS Short Message Service

SPI Serial Peripheral Interface

SRAM Static Random-Access Memory

TCP/IP Transmission Control Protocol/Internet Protocol

TTFF Time To First Fix

TX Transmit

UART Universal Asynchronous Receiver/Transmitter

UAVs Unmanned Aerial Vehicles

UBX u-blox Protocol

UDP User Datagram Protocol

UFL Ultra-Fine Coaxial Connector

USB Universal Serial Bus

USSD Unstructured Supplementary Service Data

VCC Voltage Common Collector

VRTC Voltage for Real-Time Clock

WAAS Wide Area Augmentation System

Contents

General Introduction

The Algerian Sahara, one of the largest and harshest deserts on earth, covers more than 2 million km^2 and challenges people severely when it comes to finding their way and surviving due to extreme temperatures, poisonous sandstorms, and great emptiness. It is a place very dangerous even for its inhabitants [1]. Thirst eventually claimed the lives of 12 Syrian migrants and 2 Algerians in Illizi in July 2024 because they could not find a way to get mobile network signals for help [2].

Traditional solutions like satellite phones (e.g., Thuraya or Inmarsat) offer long-distance communication but are prohibitively expensive, while VHF/UHF radios are limited in coverage and coordination. Primitive methods like trail blazes or distress signals are unreliable over vast desert distances [3, 4].

The challenge thus comes down to an affordable yet pragmatic high-tech solution, which is not just a requirement but an imperative—one that guarantees communication and position location under hostile conditions.

My device properly integrates new technology into a completely new and unique emergency communication and navigation solution designed for that hostile Sahara. It offers global, continuous coverage through a Thuraya SIM card, using the Thuraya satellite network to facilitate distress calling and location reporting anywhere in its coverage area—even in the most inaccessible places [5].

Our project is, unlike other satellite phones, light, power-efficient, and easy to use, and hence will be available to adventurers, nomads, or field personnel. In addition to satellite communication, it will also have GPS for precise navigation, an automatic damage-reporting emergency alert system through monitoring of motion patterns and vital signs, and a rechargeable solar battery for continuous use of the gadget regardless of external power sources [6, 7].

Directly linked to rescue services and securely guided to bodies of water and rescue locations, our product is a lifesaver compared to current products in price, durability, and ease of use [8]. It could vastly cut down desert deaths and guarantee safety for adventurers who confront the harsh Algerian Sahara.

This thesis is laid out in the following chapters:

Chapter 1, "Desert Challenges and Key Parts of the Device," will introduce the device and its role in exploration and safety. Matters toughly faced in desert places will be discussed—extreme heat, dust, and dehydration. The chapter will explain how the device responds to these challenges through navigation support, health monitoring, and emergency alerts. A detailed description of its three main components—the navigation system, health sensors, and energy management—will also be provided.

Chapter 2, titled "Design, Software, Testing, Economic Aspects, and Future Improvements," will focus on various aspects including hardware design, device networking, software development, algorithms, emergency protocols, and satellite communications. It will cover laboratory testing and validation, as well as distribution strategies for desert travelers. The chapter will also discuss economic considerations and propose future improvements. A summary of the envisioned future work will conclude this chapter.

Chapter 1

Desert Challenges and Key Components of The device

1.1 Introduction

The travelers and adventurers who go into the desert of Algeria would face very harsh conditions in which to fight for survival. The extremes of heat, huge sand hills, quick dehydration, and simply getting lost make it a challenge. Thus there arises an important need for good safety gear that can help people move through tough land stay healthy, and get help when needed. To solve these problems, made a clever travel safety tool that mixes modern spot finding systems with health watching features and talk skills for urgent situations. This tool will show users the closest water places and check their health condition. If there is a crisis, it can send an help signal to keep people safe all the time, especially in faraway areas. This chapter will look at how the tool works as an important link for people traveling through the desert and will talk about its importance for those crossing lonely lands. Also, it will show how the tough desert conditions causes issues due to high heat, dangers of losing water in the body, and trouble finding a way, stressing the need for specific safety measures.

1.2 Desert Challenges

Djanet, Tamanrasset, Ouargla and several other places are the desert that is big within Algeria. The arena requires special preparation because extreme temperatures and extreme aridity have appeared as an unmerciful natural law. The climate and geographical conditions of these places go through a cruel nature against the challenges of humanity. An intense temperature rise-up, sometimes over 50 degrees Celsius in peak summer, an annual challenge that is not merely for travelers and locals but even for those who dare to experience this harshness.The harsh challenges imposed by such desert areas range between extreme daylight heat, severe lack of water in case of any rain, scarcity of important vital sources like water such as oases and springs. Those have a low or poorvisibility, isolated with difficulty reaching. The absence of these water resources calls for a well-thought planning and continuous monitoring of the surrounding environment to avoid falling into a drought trap that may lead to serious health complications such as heat stress and seizures resulting from fluid deficiency.Its surface, which contains everything from giant dunes of sand to stretches that go on forever without a mark on them, further complicates the mobility factor. Starting with Tamanrasset down to ouargla , it would be very easy for a traveler in those areas to become lost without modern navigation techniques and detailed maps, thus complicating any effort to locate sources of water or safe havens in cases of emergency.Understanding the challenges of Algeria's Sahara, which joins extreme fluctuations in temperatures and a total lack of natural resources, is not just a matter of survival but a very real test of how much will and ability one has to adapt to the most difficult of circumstances. Absorbing these challenges and planning ahead for survival strategies while relying on modern technologies and local expertise-all this is a key to keeping safe and living with this peculiar natural environment.

(a) (b)

Figure 1.1: The Algerian Sahara Tadrart Rouge (Djanet)

1.2.1 Severe Dehydration and Extreme Heat

The Algerian sahara has some of the highest temperatures on the globe. Summers are extremely dangerous, as temperature can very easily exceed 50 degrees Celsius.This level of heat rapidly increases perspiration and can easily lead to severe dehydration. When a person is not hydrated and does not drink a lot of water, then they become prone to peaking heat exhaustion as well as heat strokes. One can go from dizzy and fatigued, to unconscious and having a deeply confused state which can even lead to death if the symptoms aggravate unaddressed [9]. The relative lack of water sources compounds this challenge. Oases are not only sparse, but the little groundwater that exists is not easily accessible. Traveling without full knowledge of the terrain can lead to feeling lost and trigger an inability to find useful water, and at this point, they're in trouble for sure [10].The following image illustrates the extreme heat conditions travelers face in the Algerian Sahara [11].

Figure 1.2: Traveler Facing Drought And Heat In The Algerian Sahara (Djanet)

1.2.2 Difficulty in Getting from One Point to Another

The feature of the Sahara desert that causes it to be quite impossible for one to navigate their way through the ever-spreading land is the fact that its terrain is nearly featureless. The scene keeps changing from time to time due to sand dunes blown by the wind; thus, based on this, it makes the ordinary maps and GPS less powerful. [12].

Figure 1.3: Moving Sand Dunes In The Algerian Sahara

Like this is not bad enough, sudden sand storms shift the wind direction and add to the haze. Even experienced desert dwellers get disoriented in the desert with no clue available out in the open. This makes it very easy for loses to mushroom into actualities of harsh conditions and short supplies [13].

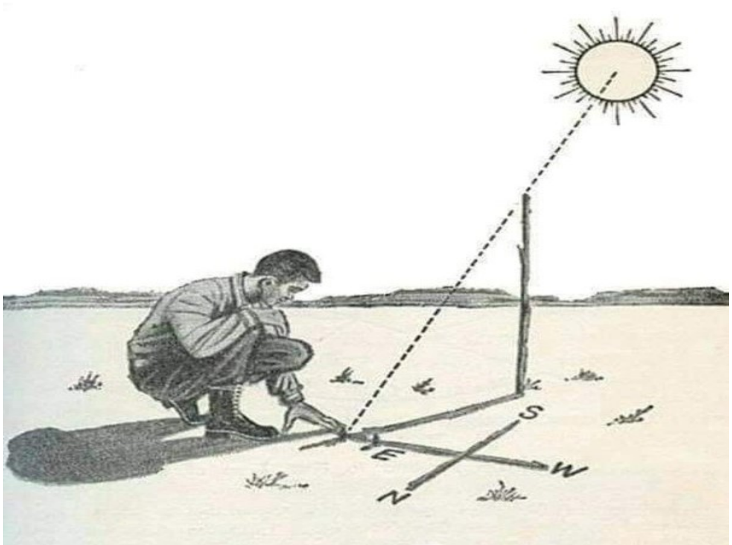


Figure 1.4: The use of the shadow of the sun as a navigational guide in the desert [14]

1.2.3 Underdeveloped Communication Systems

Although Algeria may be well built in cities, the most remote parts of the country are the Sahara which has little to no communication networks. All the regions in the desert are barely covered with mobile networks which makes asking for help in times of distress almost impossible. Due to such isolation, rescuing can be an incredibly challenging task due to the lack of ways to communicate [15]. Inability to single out their location when stranded, leads to a host of dangers including environmental factors, lack of aid, and much more [16].

Figure 1.5: No Communication Networks In The Desert [17]

1.2.4 Unpredictable Temperature Changes

In the daytime, temperatures can soar to extreme levels, however, at nighttime, temperatures can plunge to very low levels. Desert nights can get so cold that it even goes below

0 degrees Celsius. Such changes in temperatures pose a major risk for anyone lacking preparations.At such drastic drop in temperatures, the human body faces a challenge to cope with the exposure. During the at night, the shifts in temperature can heighten the risk of hypothermia. If the right clothing and shelter are not indoor, it will become increasingly hard to keep the core body warm, which could even become fatal [18].

(a) Loss of Malian nationals in the Sahara [19]

(b) Changing the features of the desert at night

Figure 1.6: Unpredictable Temperature Changes

1.2.5 Hazardous Fauna

Both snakes and scorpions, some of the most venomous animals, dwell in the Algearian Sahara. If individuals lack knowledge of the wilderness or first aid, the exposure can be extremely dangerous. Some of the most deadly creatures that reside in this region include certain species of vipers and deathstalker scorpions. the venom forms extremely painful paralzing slowly leading to death. The remote area that lack medical assistance for treating means given the conditions, it is strongly recommended to practice intensive first aid [20].

(a) Hornet snake [21]

(b) Desert Scorpion [22]

Figure 1.7: Hazardous Fauna

1.2.6 Sandstorms and Reduced Visibility

Sudden sandstorms, would not raise, with little to no warning. These storms swallow huge places in dust and sand, reducing visibility to almost nothing. Such bad visibility can make a lot of trouble in traveling, accidents, or one getting lost Besides, the rough sand particles taken by the wind can cause breathing problems and damage tools. Also, confusion because of low sight may move the travelers off their path and more endanger safety [23]. In short, the Algerian Sahara holds so much to be prepared for: through great respect for the environment and understood risks within. It is important for an inhabitant or visitor to pack in awareness of these risks and plan for their eventualities in order to navigate safely and survive in the deserts.

Figure 1.8: Sandstorms Ravage Algeria's Desert [24]

1.3 How the Device Addresses These Challenges

This intelligent machine has been designed to cope with the aforementioned challenges in achieving high survival of people in the Algerian Sahara. The most undistracted real-time navigation, and health monitoring with immediate emergency communication will lay down the most critical risks related to travels in deserts.

1.3.1 improving Navigation and Water Access

- **Global Positioning System (GPS)-Based Navigation:** The device uses high resolution GPS to assist the user in establishing his location and navigating safely through the desert. [25] .

Figure 1.9: GPS-Based Navigation [26]

- **Automated Well Detection:** The device, using pre-loaded databases and real-time geographic scanning, locates and directs the user to the nearest sources of water or wells [27].

- **Safe Route Recommendations:** Topography, weather, and terrain conditions consider to avail optimized routes avoiding dangerous areas such as shifting dunes and steep rocky slopes. [28].

- **AR Navigation:** It projects digital markers on real-world views, which helps the traveler to stay on track in conditions with poor visibility [29].

1.3.2 Health Monitoring and Emergency Response

- **Tracking of Vital Signs:**The device continuously measures body temperature, heart rate, and hydration level to detect signs related to dehydration or heat exhaustion [30].

Figure 1.10: vitals monitor [31]

- **Emergency Medical Alerts:** If a life-threatening condition like heatstroke or extreme dehydration is detected, the device automatically notifies pre-designated emergency contacts or medical services [32]

1.3.3 Overcoming Communication Challenges

Another essential survival challenge faced by people within the Algerian Sahara is that there is not a reliable communication network. Being so wide and remote, most of the time, traditional mobile networks hardly give any coverage in the desert; thus, it leaves travelers so isolated that, in case of an emergency, they cannot call for help [33].
The device incorporates several communication technologies to ensure connectivity even at the most remote site.

- **Satellite Connectivity:**Unlike the traditional mobile networks that are always dependent on the terrestrial towers, satellite communication assures a global cover. This, therefore, allows the user to send emergency alerts and be reached by a rescue team or any other person concerned no matter where the user is located.

Figure 1.11: Satellite Connectivity [34]

- **Two-Way Messaging System:**It permits a user to send and receive text messages via a satellite link. This can be basic communication when there are no mobile networks available. [35].

- **Automated Distress Signal:**It monitors your movement continuously and when it realizes that you have not been moving or moving erratically for quite some time, it will automatically send a distress signal together with GPS coordinates to responding teams. [36].

- **Emergency Network Bridging:**It generates a temporal mesh network that connects and involves several users within its effective radius, thus making it possible for stranded people to communicate among themselves so that they can create the best possible chances of being rescued. [37].

- **Solar-Powered Charging System:**Since the desert is sunny all through, the device has solar panels that keep the power sustained for long-distance communication. communication [38].

- **AI-Based Predictive Alerts:** Through analyzing the geographical speed of the user factors, and environmental conditions, it predicts potential danger zones and gives the user warning before entering such a place [39]. An Algerian Saharan traveler having this state-of-the-art communications technology in his smart device shall, at no time, be really alone. Improved time in response to rescues shortens such spells of prolonged deadly exposure to the harsh desert environment.

1.4 Key components of the device, (the navigation system, health sensors, and power management)

1.4.1 The NEO-8M GNSS Module

The u-blox NEO-8M module, a member of the NEO-8 family, is a high-end Global Navigation Satellite System GNSS receiver with support for accurate navigation and positioning. The module retains the legacy of earlier models like the NEO-7M, with enhanced sensitivity and greater GNSS compatibility. [40].

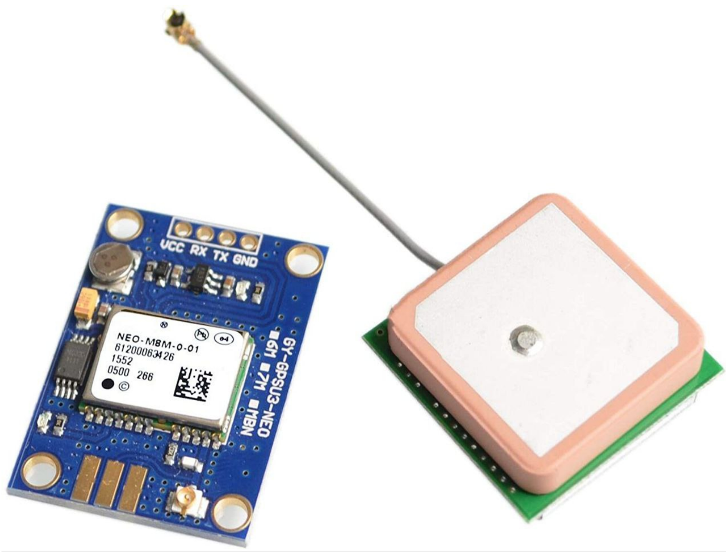


Figure 1.12: NEO-8M GNSS Module [41]

1.4.1.1 Key Features and Role of the NEO-8M GNSS Module in the Smart Device Project

The u-blox M8 engine with 72 channels powers the NEO-8M GNSS module, supporting GPS, Globalnaya Navigatsionnaya Sputnikovaya Sistema (GLONASS), BeiDou Navigation Satellite System (China) (BeiDou), Quasi-Zenith Satellite System (QZSS), and Satellite-Based Augmentation System (SBAS) (e.g. Wide Area Augmentation System (WAAS), European Geostationary Navigation Overlay Service (EGNOS), MTSAT Satellite Augmentation System (MSAS)) [40]. It provides a sensitivity of −167 dBm for tracking and −148 dBm for cold start, with an accuracy of ∼2.0 m to 2.5 m in Circular Error Probable (CEP). The module operates at 2.7 V to 3.6 V, drawing ∼40 mA to 67 mA, and features a Universal Asynchronous Receiver/Transmitter (UART) interface (Voltage Common Collector (VCC), Ground (GND), Transmit (TX), Receive (RX)) at 9600 bps, supporting National Marine Electronics Association (NMEA) and u-blox Protocol (UBX) protocols [42]. It delivers Two-Dimensional (2D)/Three-Dimensional (3D) fixes via trilateration, with cold starts at ∼27 seconds and warm starts under 1 second, aided by an Electrically Erasable Programmable Read-Only Memory (EEPROM) and backup battery for ∼1-second Time To First Fix (TTFF) warm starts. In the smart device project for the Algerian Sahara, the NEO-8M ensures precise location tracking to send emergency messages with the user's position and vital signs data to their family and the police, while guiding the lost individual to the nearest water source to ensure their survival.

1.4.2 HMC5883L GY-271 Compass Module:

The GY-271 HMC5883L is an ultra-small, three-axis digital compass created as an inexpensive electronic compass. This is HMC5883L from Honeywell with a few discrete components tacked onto the breakout board. It is used together with microcontrollers such as Arduino and Raspberry Pi (Pi) as well as GPS modules, mainly NEO-8M, for navigation, heading finding, and robotic work. It finds widespread application in microcontrollers such as Arduino,Pi, and also GPS modules like NEO-8M for navigation, heading finding, and work robotics engineering.

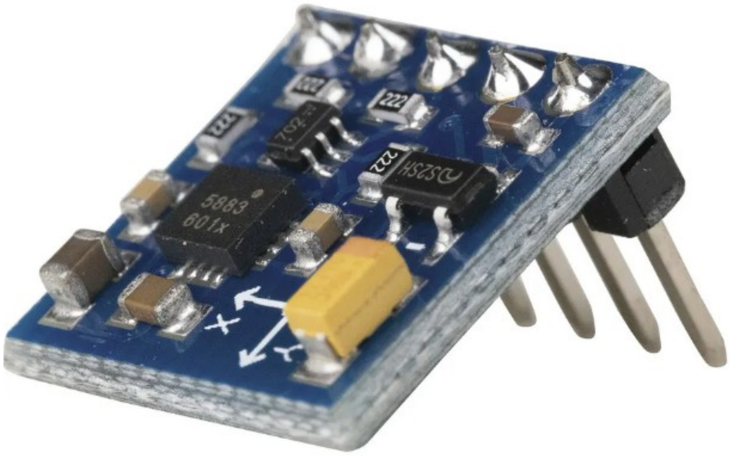


Figure 1.13: HMC5883L GY-271 Compass Module [43]

1.4.2.1 Features and key role in the project

The HMC5883L GY-271 3-axis digital magnetometer uses the HMC5883L chip having 12 bit Analog-to-Digital Converter (ADC) resolution. Measurable limits are ±1.3 to ±8.1 Gauss. Heading precision is near 1° to 2° post calibration. It operates at 2.16 V to 3.6 V (typically 3.3 V or 5.0 V with a regulator), drawing ∼100 µA in normal mode and ∼2 µA in sleep mode, and uses an Inter-Integrated Circuit (I2C) interface (address 0x1E) with Serial Data Line (SDA), Serial Clock Line (SCL), VCC, GND, and Data Ready (DRDY) pins [44]. The module, sized at 14.8 mmx13.5 mmx3.5 mm, measures the magnetic field of Earth (axes X, Y, Z) and calculates the direction (0 to 360°) using the arctangent function (atan2), requiring calibration to correct distortions [45].The HMC5883L integrates with the NEO-8M GPS module in the Algerian Sahara smart device project to provide precise direction data. .that device can find lost person regarding nearest water source and share this location along with vital signs data with police and family. [46].

1.4.3 The Pufrom Module

The Pulse Rate Sensor Module is an integrated Electronic Module used to detect human heart rate (Heart rate), expressed in beats per minute (Beats Per Minute (BPM)) or We have experienced it using Photoplethysmography (Photoplethysmography (PPG)) technology, which is a technique of measuring changes in blood volumeume within a microvascular bed of a tissue using light. This function is useful in cases like personal fitness monitoring, exercise equipment [47].

Figure 1.14: The Pulse Rate Sensor Module [48]

1.4.3.1 Key functions and roles of the heart rate sensor in the project

The Pulse Sensor uses an LED emitting green light at 550 nm and a photodiode to measure changes in light absorption by oxygenated hemoglobin, detecting blood volume changes to calculate pulse rate.It outputs an analog signal, converted to digital via an ADC for micro-controller interfacing. The sensor measures 30 beats per minute to 250 beats per minute with an accuracy of 5-10% error at rest (15-20% with movement due to motion artifacts), operates at 3.3 V or 5 V with a current below 4 mA, and has a sampling rate up to 100 Hz on a 16 mm diameter Printed Circuit Board (PCB).It emits light through the skin (e.g. fingertip), processes the reflected pulsatile waveform, and filters noise to calculate BPM.In the smart device project for the Algerian Sahara, the Pulse Sensor monitors the user's heart rate in real-time, sending vital signs data alongside their position (via NEO-8M GPS) to family and police during emergencies, ensuring timely rescue while guiding the lost individual to the nearest water source.

1.4.4 Temperature Sensor MLX90614 for Body Temperature Measurement

Melexis is the producer of MLX90614, an (Infrared (IR)) temperature sensor that has been designed for non-contact temperature detection; this component is predominantly used for human body temperature monitoring activities. The sensor perceives the amount of infrared radiation that is radiated by objects, such as the human body, and converts this into an actual temperature reading through the application of the Stefan-Boltzmann Law. MLX90614 is of paramount GmShar qualified help to the intelligent navigation security devices Bauer operates in the desert of Algeria as it monitors body temperature to initiate conditions related to high temperature from heatstroke under hot circumstances.

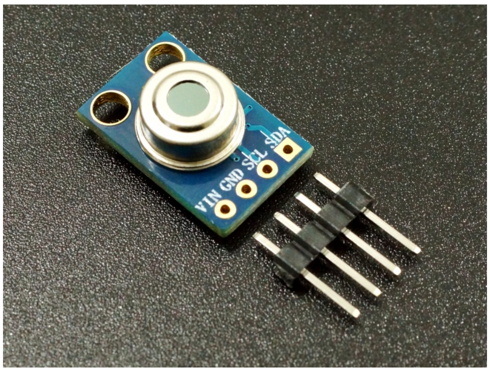


Figure 1.15: Temperature Sensor MLX90614 [49]

1.4.4.1 Main functions and roles of MLX90614 in the project

The MLX90614 measures object temperatures from -70°C to 382.2°C (including body temperature at 35°C to 42°C) and ambient temperatures from -40°C to 125°C, with a standard accuracy of ±0.5 °C (0 °C to 50 °C) and an optional ±0.1 °C for medical use (35 °C to 42 °C), and a resolution of 0.02 °C.It has a 90° Field of View (FOV), operates at 3.3 V or 5 V with a current below 2 mA, and uses an I2C-compatible System Management Bus (SMBus) interface with SDA and SCL pins, also configurable for Pulse Width Modulation (PWM) output, in a compact TO-39 package. The sensor detects IR radiation via a thermopile, processes it with a 17-bit ADC and Digital Signal Processor (DSP), and calculates temperature based on the Stefan-Boltzmann Law, requiring a 2-5 cm distance for accurate body readings. In the smart device project for the Algerian Sahara, the MLX90614 monitors the user's body temperature in real-time, sending this vital sign data alongside their position (via NEO-8M GPS) to family and police during emergencies, ensuring timely rescue while guiding the lost individual to the nearest water source.

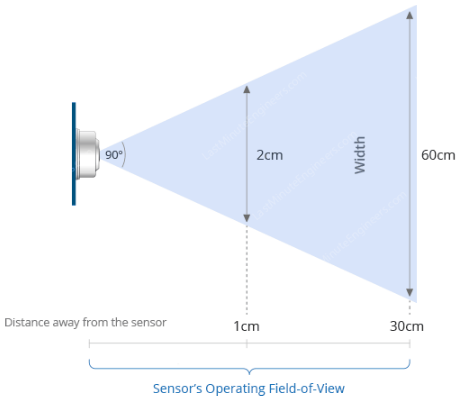


Figure 1.16: Field of View (FOV) [50]

1.4.5 SIM900 GSM GPRS

The SIM900 Global System for Mobile Communications (GSM)/General Packet Radio Service (GPRS) module is a compact unit with a gauge length of 24 mm × 24 mm × 3 mm and weighs 3.4 g.It supports quad-band 850 MHz/900 MHz/1800 MHz/1900 MHz and ensures compatibility with global GSM networks via a valid Subscriber Identity Module (SIM) card [51] [52].It provides Class 10 GPRS performance with downlink speeds up to 85.6 kilobits per second, supports CS-1 to CS-4 coding schemes, and integrates TCP/IP, UDP, PPP stack, FTP, and HTTP for Internet applications. [53].The module operates in 3.2 V to 4.8 V (ideally 3.4 V to 4.4 V), consumes 1.5 mA in idle mode, up to 216 mA during talk time, and peaks at 2 A during transmit bursts [54].It features a UART interface (1200 bit/s to 115 200 bit/s), I2C with SDA and SCL pins, 12 General Purpose Input (GPI) pins, two PWM pins, and one ADC pin (0 V to 3 V), controlled via Attention (AT) commands (GSM 07.07, 07.05, and SIMCom Wireless Solutions Ltd. (SIMCOM) extensions) [55] [56].It supports SMS, CSD, and USSD, and operates in a -40 to +85 degrees Celsius temperature range, making it suitable for harsh environments.In a project I was involved in in the Algerian Sahara, the SIM900 enabled reliable communications that led to timely rescue efforts.It sent emergency text messages containing the user's location (via the NEO-8M GPS) and vital signs to family members and police, while also directing missing persons to the nearest water source.

Figure 1.17: SIM900 GSM GPRS

1.4.6 Thuraya SIM card

Thuraya SIM cards satellite communication cards specially designed for Thuraya devices to enable connectivity in remote places such as deserts and seas where traditional cellular networks cannot reach. It is operated by Thuraya Telecommunications Company in the United Arab Emirates which supports voice, SMS, and data over GmPRS to suit the needs of explorers, workers, and travelers in remote places. Prepaid available such as NOVA SIM without monthly contracts and can be used whenever there is a need without a long-term commitment. They also include location tracking and an alert transmission that makes the users' safety and communications capabilities better in harsh environments [57] [58]. In this project, it would place a vital role in the functionality of the safety equipment satellite connectivity which implies communication within the remote desert regions of Algeria [5].It incorporates a GSM module along with other components such as a GPS module, MLX90614 temperature sensor, pulse sensor, HMC5883L magnetometer, and an LCD screen all attached to an Arduino microcontroller.This device will send alerts as well as vital signs data (and location of the person) where satellite coverage exists.It uses a Thuraya SIM for satellite-based location tracking besides normal cellular operation to keep them connected and safe when they are in isolated areas [3].

Figure 1.18: carte sim thuraya [58]

1.4.7 Arduino Uno Key Features

The Arduino Uno is based on the ATmega328P microcontroller, which operates at a frequency of 16 MHz and has 14 digital I/O pins (6 with PWM) and 6 analog input pins with 10 bit ADC (0 V to 5 V) [59] [60].It contains 32 k byte of flash (0.5 k byte for the bootloader), 2 k byte of SRAM, and 1 k byte of EEPROM, operates from 5 V (via Universal Serial Bus (USB) or 7 V to 12 V Direct Current (DC)), and consumes 50 mA [59]. when idle.The device has a size of 68.6 mm × 53.4 mm, weighs 25 g, supports UART, I2C and Serial Peripheral Interface (SPI) interfaces, has a maximum current of 40 mA per pin, a total current of 200 mA, and an operating temperature of 0 °C to 70 °C [61] [62].In this project, for the smart device in Algerian Sahara, we take Arduino Uno as the main controller.We integrate here NEO-8M GPS, HMC5883L, Pulse Sensor, MLX90614 and SIM900 GSM/GPRS modules to process location and vital signs data so that we can send emergency Short Message Service (SMS) messages to family and police and guide the lost person to the nearest water source.

Figure 1.19: Arduino Uno [63]

1.4.8 I2C LCD Key Features

The I2C Liquid Crystal Display (LCD) modules are typically 16 × 2 character displays, up to 32 characters, that use the SDA and SCL lines to integrate the LCD with the I2C interface, thus reducing the pin count of controllers such as the Arduino [64].They operate at 5 V (some versions have 3.3 V), support 100 kHz standard mode or 400 kHz fast mode, and include a PCF8574 I2C expander chip to convert the I2C signals to parallel data [65]. It consumes 1 mA to 2 mA normally, or 20 mA with backlighting, and functions within 0 °C to 50 °C [66] [67].In the smart device project for the Algerian Sahara, the I2CLCD displays real-time data such as the user's location (via NEO-8M GPS), vital signs (from Pulse Sensor and MLX90614), and directions to the nearest water source, aiding the lost individual while the SIM900 GSM/GPRS sends emergency SMS to family and police.

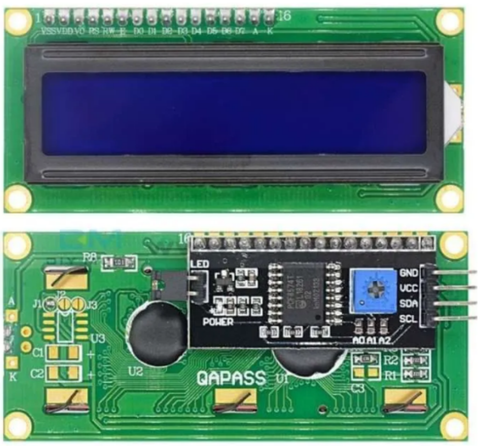


Figure 1.20: The I2C LCD

1.5 Secondary components of the device

1.5.1 Wiring and Connectivity

Arduino wiring uses jumper cables (male-to-male, male-to-female, female-to-female) to connect components like sensors and displays, with solid-core cables for breadboards and stranded cables for flexible applications [68] [69]. Wires with 22 –24 AWG gauge handle currents of 2 mA to 20 mA for sensors or 100 mA for motors, and short wires (10 cm to 15 cm) minimize resistance and noise (e.g., a 1 m wire with 0.1 Ω per meter causes a 0.1 V drop at 1 A) [70]. Color coding is best (red for power, black for ground, yellow for signals), using insulated cables, labeling (e.g., "VCC Sensor 1"), and setting a common ground on breadboard rails for stable power distribution [69]. In the smart device project for the Algerian Sahara, the wiring ensures reliable connections among Arduino Uno, NEO-8M GPS, HMC5883L, Pulse Sensor, MLX90614, and SIM900 GSM/GPRS with I2C LCD so that data can be transferred regarding location as well as vital signs and directions to the nearest water source. The setup will also allow emergency SMS communication.

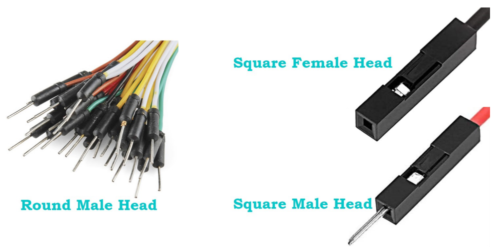


Figure 1.21: jumper wires type [71]

1.5.2 Power Management System

the power jack input of the smart device integrated with the GSM module for communication.The user shall use the internal battery or an external power source through this switch, with an arrow on the board indicating which will be the correct toggle position for use with external supply.The smart device prefers an effective 5 V 2 A power adapter, but it operates well with other options like 9 V 1 A and 12 V 1 A hence different sources of power can be considered, such as the solar panel or power bankA small solar panel for automatic battery charging on exposure to sunlight makes the device feasible for use in deserts, reducing the reliability on conventional sources of power [72]. A small solar panel for automatic battery charging upon sunlight exposure, this makes the device possible to use in deserts and also reduces the dependency on conventional power source availability [73].

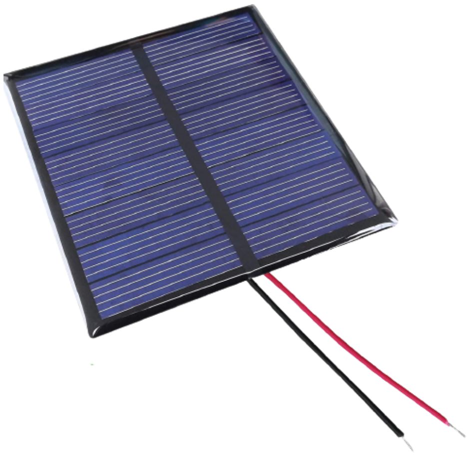
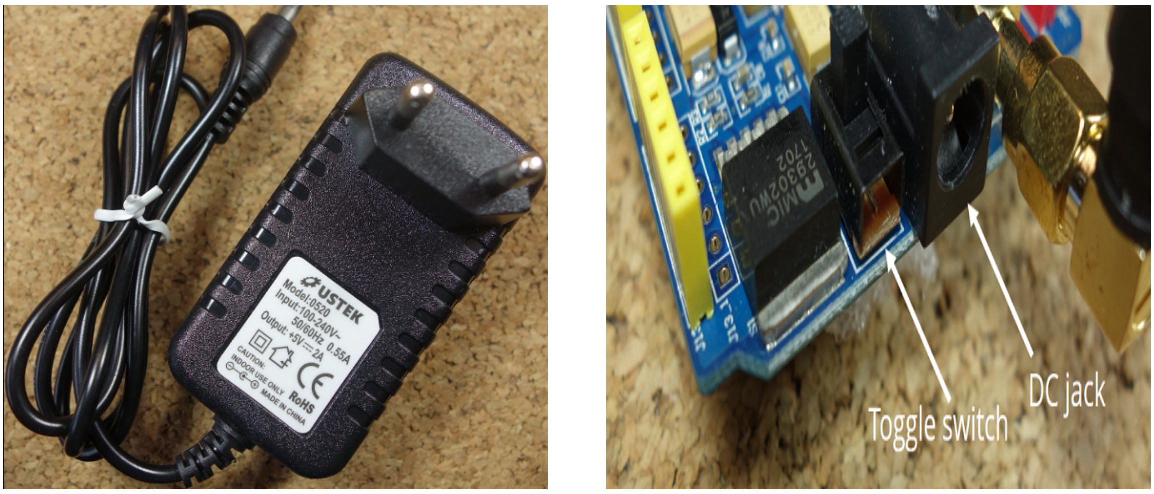


Figure 1.22: a small solar panel

In a power source vicinity, the user can select external power to save the internal battery, whereas the device itself automatically switches its power supply [74].to the internal battery in remote areas to keep the work running uninterrupted. Besides, the switch also maintains the source fighting the internal circuits hence extending the life of the device reliable in different conditions [75].



(a) power adapter [76]

(b) DC jack [76]

Figure 1.23: the right power supply

1.6 Conclusion

This chapter has dealt with various challenges that confront the inhabitants of the Algerian Sahara, where environmental conditions are hostile—particularly extreme heat and severe dehydration, coupled with unpredictable temperature variations, dangers from animals, and a communications black spot. Challenges of this nature emphasize how technological solutions that ensure reliable safety for travelers in the desert are urgently required. The proposed smart device meets these challenges by merging an advanced navigation system on the Global Positioning System, health monitoring via sophisticated sensors, and emergency communications using the Thuraya satellite network. It is this set of features that designs the device toward giving comprehensive protection to users within a harsh desert environment. This chapter lays a solid groundwork for the forthcoming one, which will cover design, software, testing, economic aspects, and future enhancements—thus sharpening our insight into the possible effects of enhancing safety in the desert.

Chapter 2

Design, Software, Testing, Economic Aspect, and Future Enhancements

2.1 Introduction

This chapter deals with the technical and strategic efforts toward developing a smart device for safety improvement in the Algerian Sahara. Challenges, as identified in Chapter 1, inform a detailed presentation of the device development process from hardware and software design through laboratory testing and economic analysis to proposed future improvements. The section on hardware design will cover the integration of key components like the GPS module, health sensors, and satellite communication systems required for efficient performance within remote environments. Software and Algorithms have to do with programming logic for navigation, health monitoring, and emergency protocols using Arduino Integrated Development Environment (IDE) and corresponding libraries. This document explains laboratory testing and validation phases that can somehow prove device reliability under simulated desert conditions. This document also covers the "Sales Strategies and Economic Aspects" section that explores the market potential, target audience, and financial feasibility of the device along with a detailed overview of its practical applications. Some suggestions have been made to increase the applicability and functionality of the device, which is an initiative from my side as a student toward innovation in developing solutions for users in challenging environments.

2.2 Hardware Design and Device Interconnection

2.2.1 System architecture and component integration

The setup is made to help people traveling through dry places in urgent times, like getting lost in spots such as the Sahara, where they could face serious problems like great thirst or trouble asking for help. It works under three main tasks: finding the way, checking health, and talking, all managed by the Arduino Uno serving as the main controlling unit [77].

In terms of navigation, the tool uses a GPS NEO-8M module to pinpoint where the user is and find out how close the nearest water source like a well is [78]. This setup also includes a GY-271 Honeywell Magneto-Compass 5883L (HMC5883L) compass for finding out which way the user is facing and giving direction details to get to the water source [79]. For health checkup, it has a pulse sensor to see user's heart beat and spot early signs of things like tiredness or lack of water [80]. Also, an Melexis 90614 (MLX90614) infrared tool checks body temp without touch, helping to find out dangers of heatstroke [81]. The communication function is handled by a SIMCom 900 (SIM900) GSM module which allows SMS messages to be sent containing the user's location or health data to emergency contacts [82]. This ability is supported by a Thuraya external antenna that gives good satellite communications in remote places [83]. Key details like the nearest well's name, how far it is, and which way to go are shown on a 16x2 LCD screen linked using I2C [84]. The device is powered by 9 V battery that's refilled with a 2 W 12 V solar panel, taking advantage of the desert's lots of sun [85]. [85].

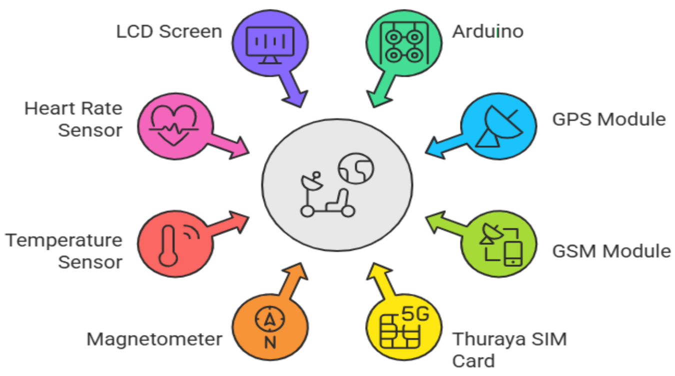


Figure 2.1: Software Arduino IDE

2.2.2 Wiring and interconnection of modules

The table below summarizes the connections between the components on a breadboard.

Table 2.1: Connections of Desert Emergency Device Components on Breadboard

Component	**Pin**	**Connected To**
Arduino Uno	5V, GND A4 (SDA), A5 (SCL)	Breadboard Power/Ground Rails Breadboard SDA/SCL Lines
GPS NEO-8M	VCC, GND TX, RX	Breadboard Power/Ground Rails Arduino D3 (RX), D4 (TX)
GY-271 HMC5883L	VCC, GND SDA, SCL	Breadboard Power/Ground Rails Breadboard SDA (A4), SCL (A5)
Pulse Sensor	VCC, GND Signal	Breadboard Power/Ground Rails Arduino A0
MLX90614	VCC, GND SDA, SCL	Breadboard Power/Ground Rails Breadboard SDA (A4), SCL (A5)
SIM900 GSM	VCC, GND TX, RX	External 9V Supply, Ground Rail Arduino D7 (RX), D8 (TX)
Thuraya Antenna	-	SIM900 Antenna Port
16x2 LCD (I2C)	VCC, GND SDA, SCL	Breadboard Power/Ground Rails Breadboard SDA (A4), SCL (A5)
9V Battery	Positive, Negative	Arduino VIN, Ground Rail
2W 12V Solar Panel	Positive, Negative	9V Battery via Regulator, Ground Rail

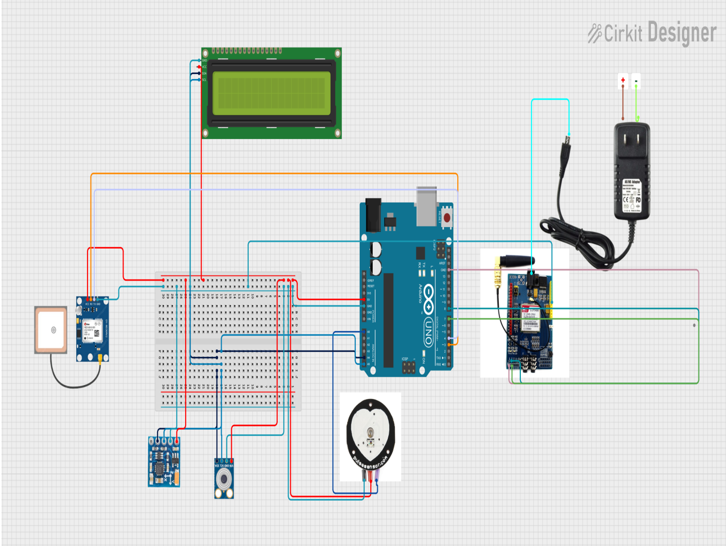


Figure 2.2: Simulation of the Desert Emergency Device

2.3 Software and Algorithms Used in the Device

2.3.1 Software Arduino IDE

The Arduino IDE is free software that can be defined as Integrated Development Environment which makes programming and developing projects based on microcontrollers easy [86].Its ease of use in terms of interface plus the support it receives from the community makes it a choice among hobbyists, students, and professionals in developing embedded systems [87].This platform utilizes a simplified version of the C / C++ programming language and supports several Arduino boards including Uno, Mega, and Nano [88]. The editor under Arduino IDE codes has features like syntax highlighting and automatic indentation; debugging can also be done through the serial monitor.This will pose no challenge to beginners who have very little experience in programming [86]. Its simple user interface and giant community support have made it popular among hobbyists, students, and professionals developing embedded systems [87].This platform works with a simplified version of C/C++ programming languages to support many Arduino boards like Uno, Mega, and Nano [88].The Arduino IDE includes a code editor with syntax highlighting and automatic indentation for codes as well as a serial monitor used for debugging.It can accommodate the needs of beginners who do not have much experience in programming [86].The other big plus about the Arduino IDE is that it runs on many libraries which makes interfacing so easy about all these hardware parts sensors communication modules displays etc [89].For instance GPS data processing, the Adafruit MLX90614 library gives you temp measurement, and SoftwareSerial lets you do serial comms.This means you can easily add fancy features without needing to know much about low-level coding [89].Plus, the IDE lets you upload code straight to the microcontroller using USB, making dev and test processes easier [87].The device uses many software libs and algos for nav, status monitoring, and comms; all of them work on the Arduino Uno platform

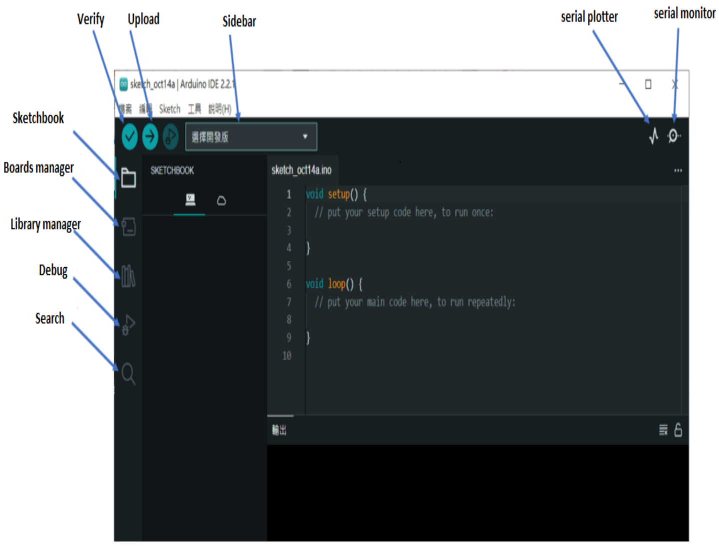


Figure 2.3: Software Arduino IDE

2.3.2 Software Libraries

The system incorporates several Arduino libraries to connect with its hardware components:

- `Wire.h`: Supports I2C communication for the LCD, GY-271 HMC5883L compass, and MLX90614 temperature sensor [90].
- `LiquidCrystal_I2C.h`: Operates the 16x2 LCD display via I2C [91].
- `SoftwareSerial.h`: Allows serial communication for the GPS NEO-8M (on pins D4 and D3) and SIM900 GSM module (on pins D7 and D8) [92].
- `TinyGPS++.h`: Processes GPS data from the NEO-8M module to obtain location coordinates.
- `Adafruit_Sensor.h`: Offers a standardized interface for Adafruit sensors.
- `Adafruit_HMC5883_U.h`: Links with the GY-271 HMC5883L compass to find the heading via I2C, supporting its specified I2C protocol (3-5V, SDA, SCL) [93].
- `Adafruit_MLX90614.h`: Oversees the MLX90614 infrared sensor for non-contact temperature measurement [94].

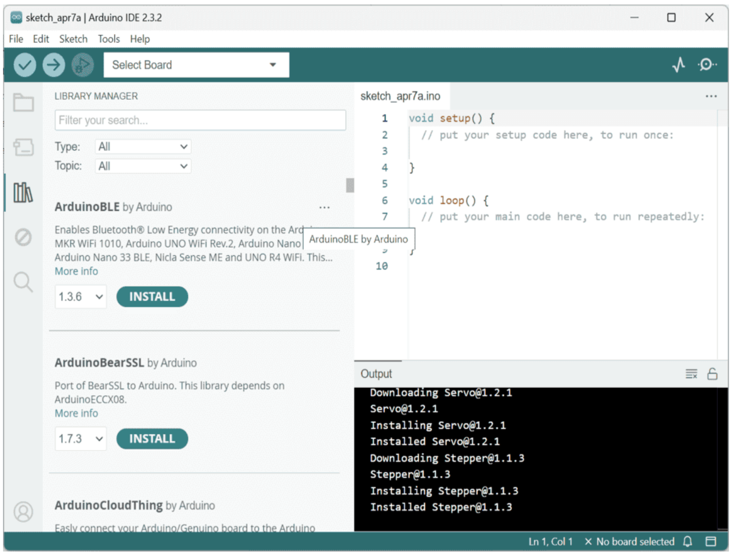


Figure 2.4: arduino library manager

2.3.3 Algorithms

This tool uses multiple methods to check information and give useful outcomes:

- **Distance Calculation** (`calculateDistance`): Uses the Haversine rule to find out how far it is from where the user is (latitude and longitude) to the well's point, taking a round Earth with radius 6371 km [95].
- **Bearing Calculation** (`calculateBearing`): Finds the direction angle between the user's spot and the closest well using trig math, fixing negative angles.
- **Nearest Well Search** (`findNearestWell`): Evaluates distances repeatedly to find out the nearest well from a predefined list of wells.
- **Heart Rate Measurement**(`measureHeartRate`): Records pulse signals for 5 seconds using the Pulse Sensor connected to pin A0 and then multiplies the result by 12 to get beats per minutes BPM [96].

2.3.4 Code Explanation

This program is a complete GPS tracking system on Arduino. It finds out the user location and shows nearby wells from a known list. Also, it can send coordinates and important data (temperature and heart rate) by SMS using a GSM module with a Thuraya SIM card for satellite communication instead of the local network; that means there will be no problem in remote areas.The `setup()` function starts everything by setting up the device and turning on the 16×2 LCD screen to show messages it also sets up the GPS module on pins 4 and 3 as well as the GSM module on pins 7 and 8 using serial software port while turning on magnetometer for finding direction plus temperature sensor.It tries to acquire a GPS signal for 30 seconds, then displays "System Ready" and supports command `g` to send the location and command `v` to send vital data.The GPS tracking system runs in the `loop()` function. The GPS data is constantly updated. If a valid signal is present, the longitude and latitude are calculated, the direction is read from the magnetometer, corrected by $+0.22°$, and the nearest well is determined using `findNearestWell()`. Distances are compared using the Haversine formula in `calculateDistance()`. The bearing to the well is calculated using `calculateBearing()`. If the angle goes off the way, the LCD shows the well name, distance, and deviation angle (with right/left/up arrow symbols). If a valid GPS signal is not found, it will show "No GPS Signal", meaning to go to an open area.This happens as `sendLocation()` creates a Google Maps link with these coordinates and sends it using `SendMessage()`, which in turn runs AT commands for the GSM module linked to the satellite through a Thuraya SIM card. `sendVitals()` sends temperature readings from the MLX90614 sensor and heart rate data measured with `measureHeartRate()`. By sensing a pulse from pin A0 for 5 seconds. The system updates its display every two seconds using delays so that stable communications can be made. This makes it good for navigation and rescue uses in far places because of its satellite link, plus it could easily make power use better or add real buttons for control.

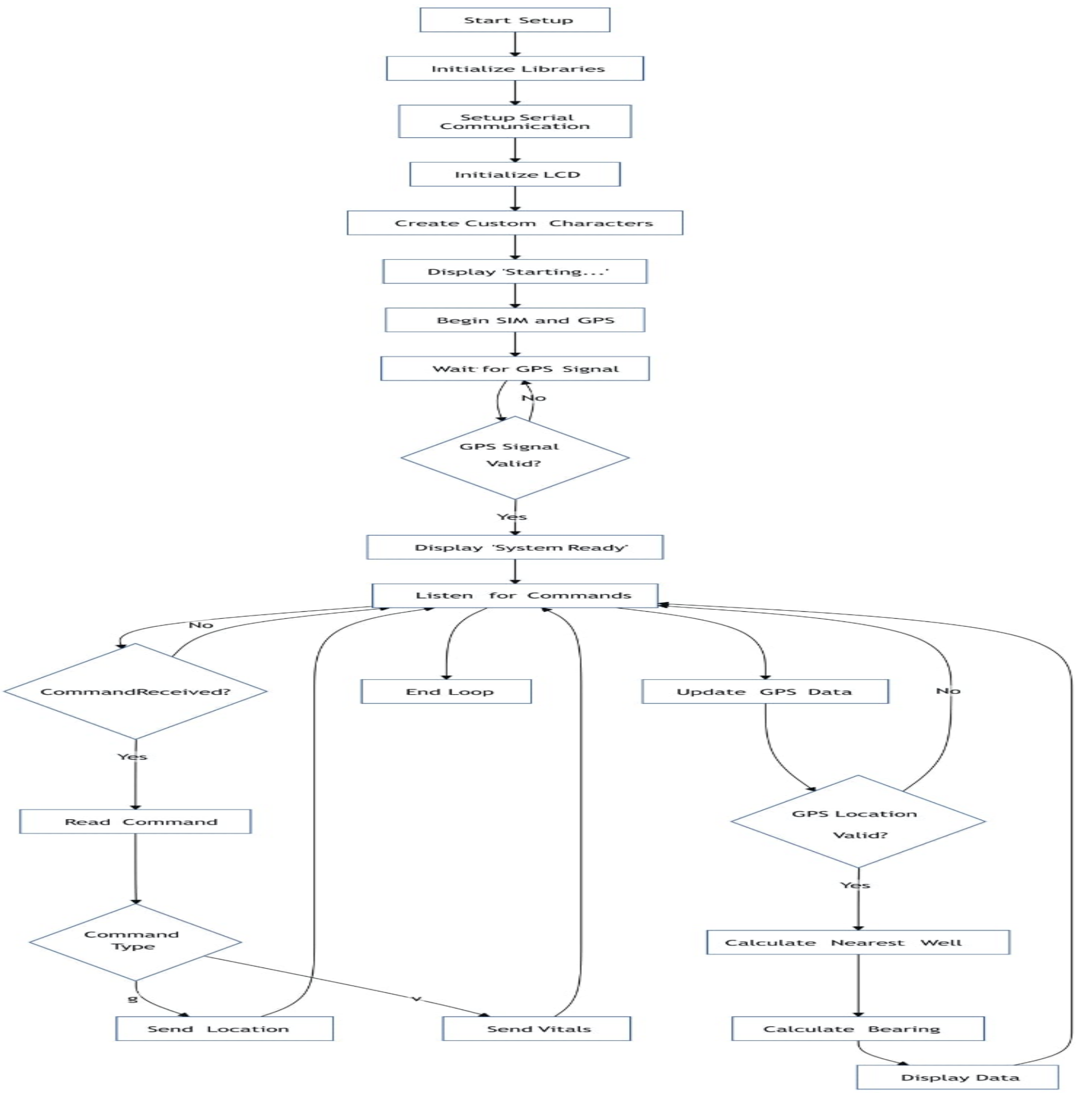


Figure 2.5: Organigram of the Desert Emergency Device

2.3.5 Functionalities

The software enables key functionalities:

- **Location Sharing (`sendLocation`)**: Transmits the user's GPS coordinates as a Google Maps link via SMS using the SIM900 module [97].
- **Vitals Sharing (`sendVitals`)**: Sends body temperature (via MLX90614) and heart rate (via Pulse Sensor) through SMS.
- **Directional guidance**: shows the near well name distance and way on the LCD using special arrow chars to show if to turn left or right or go straight based on the gap between the compass heading (from HMC5883L) and the bearing to the well.

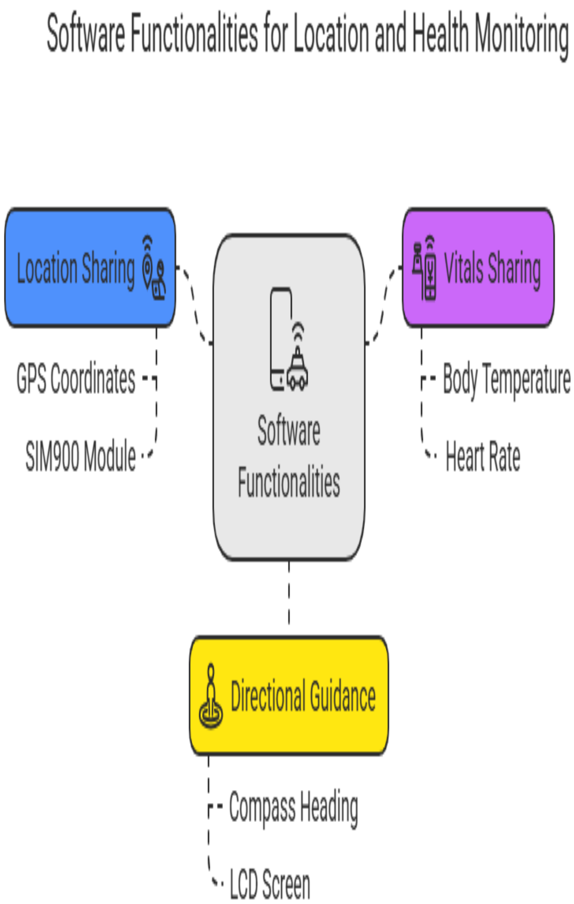


Figure 2.6: Software Functionalities Overview

2.4 Emergency Protocols and Satellite Communication

2.4.1 Sending Distress Signals Automatically

The device shall thus be seen as critical in saving lives by transmitting automated distress messages complete with the user GPS coordinates and vital signs; temperature and heart rate. For instance, if the user gets an issue with health or is misplaced in the desert, he/she shall send a distress message by a single command that reads `"Help! Loc: 24.479444,9.508569 T:36.5 C HR:72"`, to a preset contact which could be a rescue team or even a family member so that he/she can find out quickly where exactly the user is located and what condition his/her health is in. It is thus important to minimize the time taken by rescue teams to respond especially when they are located far away in such remote areas.

2.4.2 Satellite Communication in Remote Places

This equipment has a Thuraya SIM card, which will provide satellite calls and not local network coverage. Thus, the equipment will work efficiently in areas where there is no mobile network, be it a desert or mountainous place. For example, if the user's car stops in an isolated place, this device can be used to transmit an emergency signal through the satellite to convey that help should reach the user. Though it can currently support only limited modules like Iridium 9602, which offers relatively slower speed global coverage compared to some other systems, improvements can be made in worse conditions like during storms or in difficult geographical places.

2.4.3 Geo-fencing and Real-time Alerts

In the future, the device can be made to work with geo-fencing, that is defining a safe zone with specific coordinates. As soon as the user goes out of this safe zone, an alert will automatically be sent by the device to one of its contacts. For example, if someone is working near a well like `"Hassi Tifjawin"` and moves more than 5 kilometers away from it, then this device can send an alarming message `"Warning: Out of safe Zone"` to his supervisor or rescue team. This is quite helpful for places where the work environment is hazardous and may pose risks to workers in oil fields or desert locations if they wander too much from their designated work area.

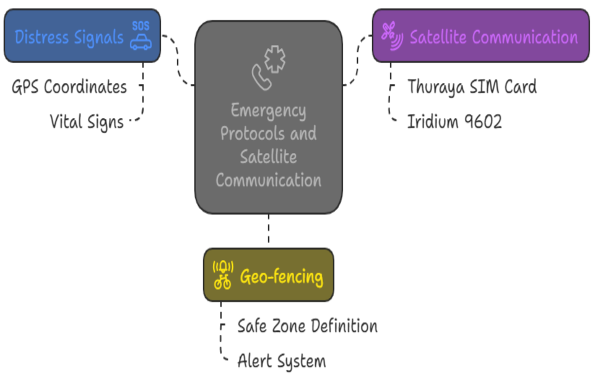


Figure 2.7: Emergency Protocols and Satellite Communication

2.5 Laboratory Testing and Validation

2.5.1 Prototype testing phases in a controlled environment

The prototype was first tested under controlled laboratory conditions to ascertain the functionality of all components making up the device. Initially, each component was tested separately—location tracking was checked using the GPS module, the GSM module for sending messages, temperature measurement with the MLX90614 sensor, pulse sensing on A0 pin using a pulse sensor, and direction determination with HMC5883L magnetometer. Testing location tracking accuracy was done by simulating coordinate signals within the lab using a GPS signal simulator. In the second stage, all components were added to one test their interactive function such as sending a message with location and vital signs. The LCD screen is tested for proper display of information e.x.well name and distance). Issues that could be detected during this phase include interference between devices as well as high power consumption

2.5.2 Checking How the System Works in Simulated Settings

After these tests, the performance of the system was evaluated under simulated conditions, likely real challenges that the device might encounter when operating in remote areas. Scenarios were simulated for instances when there is a loss of GPS signal or weak satellite communication through the Thuraya SIM card. For instance, GPS signal was deliberately interrupted for 30 seconds to test the response of the device, and it rightly flashed `"No GPS Signal"` on the LCD; this is expected behavior. High-temperature conditions (up to 50°C) were simulated to test the MLX90614 sensor; it had proven very high accuracy in measuring body temperature. Testing conditions also included different conditions for heart rate measurement (high ambient light or improper placement of the sensor), and it came out that in some situations, readings can be variable and hence needs further refinement.

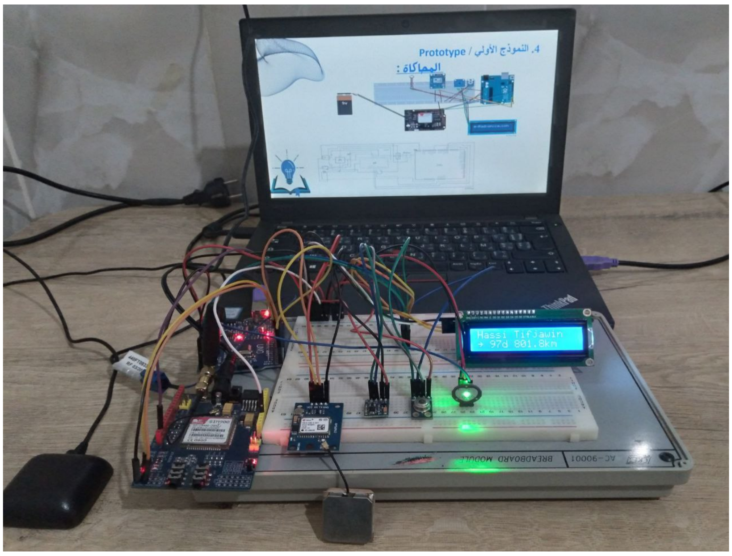


Figure 2.8: prototype of smart device

2.6 Distribution Strategy for Desert Travelers

2.6.1 Target Users (Explorers, Workers, Travelers)

Users are classified into three categories: Explorers, Workers, and Travelers. This device essentially identifies specific groups of users who operate in desert environments. The desert proves to be very tough in terms of safety, hence the need arises. First, explorers, tourists, or researchers, who go into the desert for natural exploration or geological studies, would need a device that offers location tracking and transmission of distress signals in case of emergency. Second, is the worker in desert industries, oil field workers or mineral prospectors working at remote locations such as `"Hassi Tifjawin"` well, who can use this device for their safety through geofencing and monitoring vital signs. Third, traveler whether a traditional caravan driver or a truck driver to cross the desert, will require a reliable satellite communication device so that he should not get lost or ask for help. These all bring out common needs for a device which shall improve safety within an isolated environment like deserts.

2.6.2 Ways to Make Available and Share

To make sure the device gets to the right people, different distribution methods can be used. One, local distribution centers can be set up in desert cities like Djanet, Algeria; these would work with the local government or tourism groups to give the device straight to explorers and travelers. Two, the device can be sold on travel-related online sites aimed at travelers and explorers with delivery options to places close to the desert. Three, this device can become part of a compulsory safety kit for workers in industrial companies located in the desert such as oil companies; then it will be supplied directly from their safety departments. First aid stations or checkpoints along routes that lead into the desert should have this device stocked; hence, it will be easy to obtain during emergencies.

2.6.3 Possible Collaborations and Funding Opportunities

To facilitate the dissemination and scaling up of the device, strategic partnerships could be established with various companies. This would start with satellite communication companies like Thuraya, which sells satellite connection SIM cards; this can be used to negotiate subsidized bundles comprising the device and the SIM card at a lower price. Also, to ease the distribution of the device within Algeria, partnerships can be formed with government bodies such as the Ministry of Tourism or Civil Defense. Also, international organization funding can be sought that has an interest in security within these remote territories-from agencies like the Red Cross or United Nations Development Programs. Crowdfunding sites like Kickstarter can be used to showcase this project and get fans from around the world who are explorers and travelers. All these will help fetch lower production costs plus a wider distribution network to more users.

2.7 Economic Aspect

2.7.1 Core Actions

The core actions of the project are focused on ensuring the successful development, deployment, and support of the intelligent tool designed for desert navigation and safety. The key activities include:

- Creation and production of the intelligent tool.
- Improving place finding and talking technologies in far off lands.
- Looking at user information to make sure of their security.
- Giving maintenance and tech support services.

These actions make sure that the machine is not just working but also dependable and easy to use in the tough desert conditions.

2.7.2 Aim of the Project

The project aims to solve the key issues faced by people in desert areas by offering a clever, combined answer. The exact goals are:

- Make a smart tool that helps people find wells fast and safely.
- Better talk tech in hard-to-reach desert areas.

- Lower dangers linked to people losing their way in the desert.
- Join precise health check systems to lower health threats.
- Give quick help services to users in risky circumstances.
- Help desert communities by using technology to improve their daily lives.

2.7.3 Market Segments

The target market for the smart device includes various groups that operate in or travel through desert regions. The key market segments are:

- Groundwater farmers and Bedouin nomads.
- Desert-region energy and exploration firms.
- Desert-area relief and humanitarian teams.
- Water resource management and individual protection governmental entities.
- Desert trip travel and adventure agencies.

2.7.4 Competitive Intensity Assessment

The competitive landscape for the smart device includes both direct and indirect competitors. Key points of the assessment are:

- Possible rivals are firms that make satellite communication and tracking devices.
- Options such as old GPS tools and mobile apps serve as alternatives.
- The project will have a competitive advantage by integrating location tracking with health monitoring and emergency response.
- This creates a great opportunity for market penetration due to the lack of such products in the country.

The integration of advanced features positions the device as a unique solution in the market, particularly in Algeria, where similar products are scarce.

2.7.5 Costs and Expenses

The financial feasibility of the project depends on a clear understanding of both fixed and variable costs. Cost structure is as follows: **Fixed Costs:**

- Research and development: 5,000,000 DA (one-time cost in 2025).

- Manufacturing Equipment and Infrastructure: 8,000,000 DA (one-time cost in 2025).
- Administrative and Human Resources Costs: 1,500,000 DA per year (with a 10% annual increase).

Variable Costs:

- Cost of Producing Each Unit: 30,700 DA.
- Distribution and Marketing Costs: 1,000,000 DA per year (with a 15% annual increase).
- Maintenance and Technical Support Costs: 500,000 DA per year (with a 15% annual increase).

The following is a detailed breakdown of operating costs over the 5-year period from 2025 to 2029, reflecting unit production, administrative expenses, and other operational costs.

	2025	**2026**	**2027**	**2028**	**2029**
Production (DZD)	61,400,000	70,610,000	81,211,500	93,393,400	107,344,600
R&D (DZD)	5,000,000	0	0	0	0
Manuf. Equip. (DZD)	8,000,000	0	0	0	0
Admin. (DZD)	1,500,000	1,650,000	1,815,000	1,996,500	2,196,150
Dist. & Mark. (DZD)	1,000,000	1,150,000	1,322,500	1,520,875	1,749,006
Maint. (DZD)	500,000	575,000	661,250	760,437	874,502
Total Costs (DZD)	77,400,000	73,985,000	85,010,250	97,671,212	112,164,258

Table 2.2: Operating Costs Over 5 Years (2025–2029)

2.7.6 Revenue Projections

The sales forecast has been prepared under the assumption of a target price per unit of 40,000 DA and an annual growth rate in sales of 15%.The first-year (2025) forecasted sales are 2,000 units, giving an estimated yearly sales value of 80,075,000 DA (adding on extra services).By the fifth year (2029), this number will go up to 3,498 units; the corresponding sales volume value being estimated at 139,995,000 DA.

Below is a detailed breakdown of the revenue forecast including product sales and other services maintenance and troubleshooting.

	2025	**2026**	**2027**	**2028**	**2029**
Units Sold	2,000	2,300	2,645	3,042	3,498
Product Sales (DZD)	80,000,000	92,000,000	105,800,000	121,680,000	139,920,000
Maint. Service (DZD)	25,000	25,000	25,000	25,000	25,000
Prob.-Solving Service (DZD)	50,000	50,000	50,000	50,000	50,000
Total Revenue (DZD)	80,075,000	92,075,000	105,875,000	121,755,000	139,995,000

Table 2.3: Revenue Projections Over 5 Years (2025–2029)

The net profit which is total revenue less total operating costs has been articulated below. The project makes n profit from the first year and the succeeding years keep on increasing.

Year	Revenue (DZD)	Total Costs (DZD)	Net Profit (DZD)
2025	80,075,000	77,400,000	2,675,000
2026	92,075,000	73,985,000	18,090,000
2027	105,875,000	85,010,250	20,864,750
2028	121,755,000	97,671,212	24,083,788
2029	139,995,000	112,164,258	27,830,742

Table 2.4: Net Profit Over 5 Years (2025–2029)

2.7.7 Revenue Streams

Financial sustainability is achieved as the project generates income through multiple streams. These include::

- Sale of smart devices to individuals and organizations: 40,000 DA per unit (80,000,000 DA in the first year for 2,000 units).
- Maintenance service at 5,000 DA (25,000 DA annually).
- Problem-solving service at 10,000 DA (50,000 DA annually).
- Monthly subscriptions for communication and monitoring services.
- Advisory services for firms and corporations.

The total profit for the 5-year period, summing the annual net profits, demonstrates the strong financial potential of the project.

	2025	2026	2027	2028	2029	Total
Net Profit (DZD)	2,675,000	18,090,000	20,864,750	24,083,788	27,830,742	93,544,280

Table 2.5: Total Profit Over 5 Years (2025–2029)

2.7.8 Timeline of the Undertaking

The project timeline outlines the steps required to achieve the objectives, broken down into individual activities:

- Examine the needs and wants of the market and clients to satisfy their requirements.
- Investigate to create the new technologies and approaches needed to reach the final objective.

- Plan and build the prototype, improve it, and produce a polished first version.
- Test and evaluate prototypes to ensure successful performance according to the stated specifications.
- Make and submit the application to appropriate authorities, and verify the legal process for obtaining a patent.
- Develop marketing and sales plans to aid in publicizing the new product or technology based on the patent upon acquisition.

The project timeline outlines this according to how it would help achieve the objectives broken down into activities.

Step	**Activity**
1	Research in patent databases and gather information
2	Start laboratory tests to prepare the prototype
3	Test the prototype
4	Test the prototype outside the laboratory
5	Register the patent to obtain the filing number and industrial protection
6	Follow up on the patent application process and address INAPI examiner's comments

Table 2.6: Project Timeline Activities

2.7.9 Business Model Canvas

The table below depicts the overview of the project attributes that are modeled in the Business Model Canvas

<table>
<tr><th>Key Partnerships</th><th>Key Activities</th><th>Value Proposition</th><th>Customer Relationships</th><th>Customer Segments</th></tr>
<tr><td>- Collaboration with telecommunications companies to ensure Thuraya chip and satellite coverage.
- Relations with relief organizations and government bodies to aid the project.
- Cooperation with health and tracking sensor providers.
- Partnership with manufacturers of electronic devices and components.</td><td>- Building and creating the smart apparatus.
- Improving location tracking as well as communication technologies in rural regions.
- Reviewing user data for safety assurance.
- Offering upkeep and tech support services.</td><td>- A locally unavailable product depending on modernized technology.
- Gives user safety in remote locations.
- Simple to use and set up requiring not much technical knowhow.
- Gives instant emergency alerts plus nonstop communication assured.</td><td>- Giving continuous tech support by phone as well as via applications
- Providing a clear user manual alongside the device
- offering upkeep plans plus constant upgrades.</td><td>- Desert travelers and farmers.
- Relief and emergency organizations.
- Governmental entities and civil defense.
- Eco-tourism and adventure companies.</td></tr>
<tr><td colspan="2">Key Resources
- Advanced tracking and communication technology.
- Database of wells and desert areas.
- Research and development teams to improve performance.
- Funding for production and distribution.</td><td colspan="3">Channels
- Direct online sales.
- Collaboration with stores specializing in survival and safety equipment.
- Distribution through governmental and relief entities.
- Exhibitions and technology events.</td></tr>
<tr><td colspan="5">Cost Structure
- Fixed Costs:
- Research and Development: 5,000,000 DA.
- Manufacturing Equipment and Infrastructure: 8,000,000 DA.
- Administrative and Human Resources Costs: 1,500,000 DA annually.
- Variable Costs:
- Cost of Producing Each Unit: 307,00 DA.
- Distribution and Marketing Costs: 1,000,000 DA annually.
- Maintenance and Technical Support Expenses: 500,000 DA annually.</td></tr>
</table>

Table 2.7: Business Model Canvas Overview

2.8 Future Improvements

the device is useful only in desert conditions, but its invention opens up further development possibilities that can work toward improving its functions, adaptability, and market reach. The following improvements are intended to keep the device competitive and meet the changing needs of users in various challenging terrains and deployment circumstances:

- **Application of Artificial Intelligence in Predictive Analytics:**With the ability to learn from continuously incoming data, machine learning algorithms can refine predictions about possible risks using information gathered from the sensors of the device (GPS location and vital signs such as heart rate sensed by pulse sensor and body temperature detected by MLX90614 sensor) as well as environmental conditions. For example, it might learn over time, with continuous input regarding these vital parameters and comparison with past data, to recognize that there is an ongoing pattern suggesting stroke or dehydration for this individual. In addition, predictive models can predict environmental threats based on current climatic situations and historical data - like a sudden sandstorm in a desert or an avalanche in mountains. Therefore, the devices will also be capable of alerting by sending early warning signals including suggestions for precautionary measures environments

- **Expanding device use in jungles, mountains, and seas:** Equipment made for the desert can easily be modified and re-adapted to suit other harsh environments like jungles, mountains, or seas so that they broaden their market applications. In the jungle, everything from GPS accuracy to moisture-proofing components could help navigate thick canopies where satellite signals are usually weak. For rugged mountain terrain, a device might need an altitude sensor along with a tough casing capable of withstanding temperatures and pressures typical of such environments. At sea, devices should be made waterproof (for instance, IP68) and should contain an emergency signal that is recognizable by maritime rescue systems — giving a clear indication of usability during sea-based rescue operations. Such modifications mainly demand changes in hardware materials toward more robustness and updates in software for environmental data relevant to the new application area Increasing the device's use scope to these areas will turn it into a flexible safety instrument for a broad spectrum of users from climbers to marine researchers and jungle explorers enhancing its.

- **Improved Connectivity and Multi-User Tracking:** Increasing the device's use scope to these areas will turn it into a flexible safety instrument for a broad spectrum of users from climbers to marine researchers and jungle explorers enhancing its Enhancing the device connectivity and adding multi-user tracking features will make it apt for group expeditions and large-scale operations. At present, the device employs a GSM module and Thuraya SIM card for satellite connectivity, ensuring communication in remote regions. Better connectivity might bring the integration of other communication protocols like LoRa technology that would enable low-power long-range communications among several devices in places where there is neither cellular nor satellite reception. This will keep a set of users, like a research team or workers, connected with real-time location data even in the deepest desolation. Also, you can do multi-user tracking by making a central system where a base station or mobile app watches the place and important signs of many users at once. For example, team leaders can see the health and spot of all team members from one place and get alerts if someone has a problem. This feature helps a lot with industrial jobs, like oil field missions in the desert or search and rescue teams in other lands; it makes for better coordination and safety.

2.9 Conclusion

This chapter has elaborately examined the story of smart device development that covers hardware design, software, testing, economics, and future improvement potential. The hardware setup of an Arduino microcontroller supported by a GPS module, health sensors, and satellite communication unit provides a solid solution to the challenges of navigation and safety in the desert. The software created from the Arduino IDE and custom algorithms provides accurate navigation, real-time health monitoring, and reliable emergency communication confirmed through rigorous laboratory testing. Sales strategies coupled with economic analysis highlight the market potential for the device for exploration workers and travelers in desert areas as well as its capability of generating sustainable profits. In addition, future improvements are proposed, such as integrating artificial intelligence, using it in new places, and improving links, creating new opportunities for gadget growth and success. This part finishes the detailed look at the tool, making way for a wider thought about its importance in the overall end of this dissertation.

General Conclusion

This work marks a significant milestone in our study, demonstrating our commitment to addressing real-world challenges through intellectual inquiry and inventive technological solutions. The primary objective was to design and develop an intelligent device intended to enhance the safety of individuals traveling through the Algerian Sahara—a region renowned for its extreme climate and life-threatening conditions.

Chapter 1 explored the various challenges faced by travelers in the Algerian Sahara Desert. These include intense heat, rapid dehydration leading to severe health risks, sudden temperature fluctuations, threats from wild animals, and, most critically, the lack of communication infrastructure in remote areas. Such conditions highlight the urgent need for a technology-driven solution that can serve as a reliable lifeline for anyone navigating these harsh environments.

To address these challenges, this thesis proposes a smart device that integrates several advanced features: GPS-based navigation, real-time health monitoring through vital sign sensors, satellite communication via the Thuraya network, and a rechargeable solar battery for uninterrupted operation, independent of external power sources. This chapter thus laid the foundation for a detailed technical development by establishing a clear understanding of the environmental conditions and their implications.

Chapter 2 focused on the technical and strategic aspects of the device's development, including its design, implementation, testing, and economic feasibility. The hardware system is built around the Arduino microcontroller, efficiently interfacing with a GPS module for accurate location tracking, health sensors for vital sign monitoring, and satellite modules to maintain emergency connectivity even in remote areas.

The software was developed using the Arduino IDE with custom algorithms that support real-time navigation, health monitoring, and automated emergency response protocols. These systems were validated through extensive laboratory testing under simulated desert conditions.

In terms of market viability, an economic analysis and distribution strategy were developed with the goal of targeting explorers, nomads, field workers, and travelers. The pricing model aims to ensure accessibility and sustainability. Future improvements may include incorporating artificial intelligence for predictive analytics, expanding the device's capabilities into other extreme environments such as forests, mountains, and oceans, and introducing multi-user tracking to enhance rescue coordination. These upgrades demonstrate the potential for scalability and relevance in evolving technological landscapes.

Beyond its technical innovations, this study carries a meaningful humanitarian mission. The device represents a tangible solution to a critical safety gap, offering a dependable tool for those working, exploring, or traveling in remote, high-risk regions. Its integrated GPS ensures reliable pathfinding in areas where traditional navigation methods fail. Meanwhile, health monitoring features offer early detection of life-threatening conditions such as dehydration or heatstroke, enabling swift intervention.

Satellite communication, powered by the Thuraya network, addresses the limitations of terrestrial networks, ensuring that emergency help is accessible even in the furthest reaches of the Sahara.

As a student, I take great pride in this achievement. It reflects not only a technological innovation but also a deep sense of responsibility toward preserving human life in the world's most unforgiving environments.

In a broader context, I believe this work makes a valuable contribution to the field of telecommunications by showcasing how technology can be effectively applied in extreme settings to create real, life-saving impact. The knowledge gained—particularly in hardware-software integration, remote communication systems, and user-centered design—sets a strong precedent for future research and development of smart, ruggedized devices.

With further enhancements, this solution holds promise for applications in disaster response, high-altitude operations, and maritime safety—areas where connectivity and survivability are equally critical. This underlines the solution's flexibility and its potential for lasting, global impact.

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