DESIGN AND DEVELOPMENT OF DGPS FOR THE TRACKING OF FISHERMAN / MARINE MOVING OBJECT

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Certification

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Design and Development of DGPS for the Tracking of Fisherman / Marine Moving Object

Sustainable Development Goals

(Please tick the relevant SDG(s) linked with FYDP)

SDG No	Description of SDG	SDG No	Description of SDG
SDG 1	No Poverty	SDG 9 ✓	Industry, Innovation, and Infrastructure
SDG 2	Zero Hunger	SDG 10	Reduced Inequalities
SDG 3 ✓	Good Health and Well Being	SDG 11	Sustainable Cities and Communities
SDG 4	Quality Education	SDG 12	Responsible Consumption and Production
SDG 5	Gender Equality	SDG 13	Climate Change
SDG 6	Clean Water and Sanitation	SDG 14 ✓	Life Below Water
SDG 7	Affordable and Clean Energy	SDG 15	Life on Land
SDG 8	Decent Work and Economic Growth	SDG 16	Peace, Justice and Strong Institutions
		SDG 17	Partnerships for the Goals

Range of Complex Problem Solving			
	Attribute	**Complex Problem**	
1	Range of conflicting requirements	Involve wide-ranging or conflicting technical, engineering and other issues.	✓
2	Depth of analysis required	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.	
3	Depth of knowledge required	Requires research-based knowledge much of which is at, or informed by, the forefront of the professional discipline and which allows a fundamentals-based, first principles analytical approach.	✓
4	Familiarity of issues	Involve infrequently encountered issues	✓
5	Extent of applicable codes	Are outside problems encompassed by standards and codes of practice for professional engineering.	
6	Extent of stakeholder involvement and level of conflicting requirements	Involve diverse groups of stakeholders with widely varying needs.	✓
7	Consequences	Have significant consequences in a range of contexts.	
8	Interdependence	Are high level problems including many component parts or sub-problems	

Range of Complex Problem Activities			
	Attribute	**Complex Activities**	
1	Range of resources	Involve the use of diverse resources (and for this purpose, resources include people, money, equipment, materials, information and technologies).	✓
2	Level of interaction	Require resolution of significant problems arising from interactions between wide ranging and conflicting technical, engineering or other issues.	
3	Innovation	Involve creative use of engineering principles and research-based knowledge in novel ways.	✓
4	Consequences to society and the environment	Have significant consequences in a range of contexts, characterized by difficulty of prediction and mitigation.	✓
5	Familiarity	Can extend beyond previous experiences by applying principles-based approaches.	

Abstract

Fishing is one of the most dangerous professions in Pakistan which causes 100,000 deaths per year. The fishermen must make deep dives into rivers/oceans and move undirected in search of the fishes. In many cases, the tracking of the boats is lost as very few uses the global positioning system (GPS) which gives less precision and accuracy. Therefore, we are designing a location tracking system with differential correction techniques to enhance the quality of location data gathered using GPS receivers. Differential correction can be applied in real-time directly in the field/sea to the moving boats. This enables the autonomous tracking and enhance the capability of the GPS to improved location accuracy to less than 1 meter, send the alerts to fisherman, and make the monitoring stations aware of the fisherman location. The project is developed focusing mainly on marine applications for tracking moving marine crafts and safety of the fisherman. However, the project finds its application in commercial systems e.g., tracking containers or vehicles, safe fishing, precision farming and other precise tracking. It also applicable and demanded in the defense system in navigation, surveying, target locations and others. The project aims to engineer the Differential GPS on an industrial-grade system using low-powered components. It provisions sustainable and economic development, national and human life expectancy through enhanced technological, and technical support.

Acknowledgement

We truly acknowledge the cooperation and help make by **Dr. Rukaiya**, **Assistant Professor** of **Sir Syed University of Engineering & Technology.** She has been a constant source of guidance throughout the course of this project. We would also like to thank **Mr. Farooq Ahmed Jugnoo** from **GM (Tech)-MTC, NESCOM** for his help and guidance throughout this project.

We want to thank NESCOM for funding the development of this project. We would like to thank management of Sir Syed University of Engineering and Technology for their support, our friends, and families whose silent support led us to complete our project.

Undertaking

We certify that the project **Design and Development of DGPS for the Tracking of Fisherman / Marine Moving Object** is our own work. The work has not, in whole or in part, been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged/ referred.

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List of Acronyms

Baud rate	Data transmission rate
BS	Base Station
BPS	Bits PER Second
DGPS	Differential Global Positioning System
GPS	Global Positioning System
GNSS	Global Navigation Satellite System
LCD	Liquid Crystal Display
LOS	Line-of-Sight
MS	Mobile Station
RTK	Real-Time Kinematics
SBAS	Space Based Augmentation System
UART	Universal Asynchronous Receiver-Transmitter
UI	User Interface

Chapter 1

1.1 Introduction

Global Positioning System (GPS) is a space-based radio navigation system that broadcasts highly accurate navigation pulses to users. GPS was in operation by the mid-1980s and was initially developed for military use. The first NAVSTAR (Navigation Signal Timing and Ranging) satellite was launched in 1994. Despite military usage, GPS technology could be used by civilians. It was introduced in a cell phone in 1999, which also began appearing in automobiles, but the information received was not as accurate as the militaries because of Selective Availability (SA). The GPS unit was used to provide a location little over 300 feet (about 100 meters). Therefore, in May 2000, SA was disabled, and the users could get the accuracy within about 50 feet (15 meters) [1]. In 2000, the US government planned to add three GPS satellites for non-military use as a national resource for navigation. There was then an exponential growth in GPS usage for in-car navigation, location-based services, personal technology, usage in logistic tracking, and other industries.

Among many applications, GPS is the fastest method to provide accurate speed measurement and navigation for mariners. While at sea, accurate position, speed, and heading are needed to ensure the vessel reaches its destination in the safest, most economical, and timely manner that conditions will permit. As the vessel departs from or arrives in a port, the need for accurate position information becomes even more critical, where vessel traffic and other waterway hazards make maneuvering more complicated, and the risk of accidents increases, especially in poor weather. Many countries also use GPS for buoy positioning and dredging to improve harbor navigation.

1.1.1 GPS-based Tracking

GPS networks consist of 24 satellites that operate in six different orbital paths spaced to cover at least five satellites from any point on Earth. Each satellite continuously transmits signals to the GPS device, which is stationary or moving on the ground. The signals are used to collect the coordinates information. The receiver can estimate its location based on latitude, longitude, and altitude by locking on the signals of at least three satellites, commonly known as *trilateration*, as shown in Figure 1. The receiver can also get other useful information such as speed, route, trip distance, distance to destination, sunrise, and sunset time.

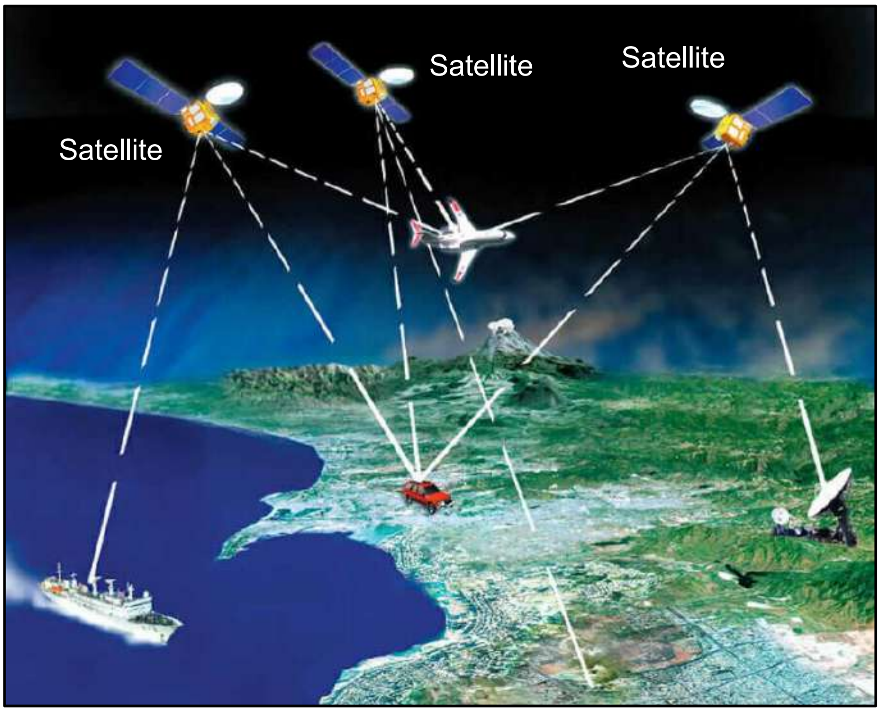

Figure 1: GPS-based tracking using trilateration.

GPS tracking requires a device to be installed in a vehicle or any object being tracked. The device provides the exact location and subsequent movement, enabling real-time object tracking. The GPS uses the Global Navigation Satellite System (GNSS) network, consisting of satellites communicating with GPS devices. Three major GNSS systems are operating: United States GPS, the Russian Federation's Global Orbiting Navigation Satellite System (GLONASS), and Europe's Galileo system. These systems provide information on the tracked object's current location, direction, time, and speed.

1.1.2 Improving GPS Accuracy

GPS accuracy in longitude and latitude coordinates is 10-15 meters. Sometimes, it is more precise, but it depends on the variety of factors discussed above. In altitude, the accuracy is reduced to 50% regarding the longitude and latitude obtained.

There are models available that compare the relative speeds of the two-timing signals and can provide location accuracy to within half an inch but could be more cost-effective. The systems that enhance positional accuracy are Differential Global Positioning System (DGPS), Assisted Global Positioning System (AGPS), Real-Time

Kinematics (RTK), extended Differential (e-Dif), and others. Among these, DGPS can provide cost-effective and accurate positioning. In the required distance of 500 meters, the DGPS can provide accuracy up to 1-3 meters, having a reference station around [2][3].

1.2 Statement of the problem

In many cases, the tracking of the boats is lost as very few use the GPS systems and mostly communicated the sea conditions through radio communications. However, the GPS also lacks in identifying the exact location. Differential correction can be applied in real-time directly in the field/sea or when post-processing data in the office/coast. Although both methods are based on the same underlying principles, each accesses different data sources and achieves different levels of accuracy. Combining both methods provides flexibility during data collection and improves data integrity. A single GPS receiver from any manufacturer can achieve accuracies of approximately 10 meters. To achieve the accuracies needed for quality GIS records—from one to two meters up to a few centimeters—requires differential correction of the data. Most data collected using GPS for GIS is differentially corrected to improve accuracy.

1.3 Project Objectives

The objective is to develop a low-cost and high-performance DGPS that can achieve the industrial-grade accuracy of tracking moving objects/fisherman boats. A typical GPS receiver provides 3 meters to 6 meters of accuracy using two GPS positions, making it inappropriate for precise location tracking. Therefore, DGPS is developed to provide accurate relative coordinates between two GPS positions. DGPS can increase the GPS accuracy upto 1 meter in an open environment and send the alerts to fisherman and make the monitoring/ control stations aware of the fisherman location.

The DGPS system requirements to achieve the required objectives are listed in Table 1 and Table 2, respectively.

Components	Requirements
GPS Receiver	1. Provides positioning data, received from satellites, and communicated to the microcontroller. 2. Gives better coordinates value particularly for the moving station. 3. Low-cost, low power consumption, and high precision.
Communications	1. Transmission of GPS data from mobile station to base station 2. Work in a wide area environment and meet distance requirements. 3. Error correction is desirable and applied.
Microcontroller	1. Sufficient computational power and memory for computations. 2. Minimum of 3 UART / Serial Communication channels. 3. Low power consumption.

Table 1: DGPS System Requirements to achieve the objectives.

Aspects	Outcomes
Accuracy	1. Within 1 meter to 1.5 meters. 2. After differential corrections, accuracy can be <1 meter.
Operation	1. Operational environment of wide-open areas. 2. Update frequency of 1 second or greater. 3. Low power consumption.
Output	1. Serial communication output. 2. Graphical interface shows object tracking, relative position, speed, error, and accuracy.
Cost	1. Low cost and high efficiency.

Table 2: DGPS System Outcomes

1.4 Motivation

GPS provides 24-hour coverage worldwide but has limitations, including the requirement of line of sight (LoS) between the GPS antenna and four or more satellites. Obstructions such as buildings, overpasses, and other obstacles shield the antenna from the satellite and can potentially weaken the signals. It makes it difficult for the system to ensure a reliable position. However, these issues mainly occur in urban areas and cause multi-path interference. The obstruction relies on distance and atmospheric impulsion in open fields like oceans and seas.

GPS signals from satellites down to the ground must traverse layers of the Earth's atmosphere and be delayed. Subsequently, a moving object cannot be labelled precisely on the inaccurate GPS coordinates. Furthermore, the available DGPS solutions are costly. Therefore, there is a dire need to develop a low-cost and more accurate positioning system to locate moving objects in a real-time environment.

1.5 Assumption and Dependencies

1.5.1 GPS Accuracy

The most up-to-date navigation services, such as Google Maps, can pinpoint the user's location with minimum faults of 3-10 meters [4]. Several factors limit GPS accuracy, where the major source arises from the fact that the radio signal speed is constant only in a vacuum. The problem is that the device needs to receive signals from at least 3-4 satellites at a time to provide accurate location data. However, during rain, water evaporation and other particles in the atmosphere can affect the signals and cause propagation delays [5]. Multipath fading also occurs when signals bounce off a terrain or building before reaching the receiving antenna, which causes errors in location data and reduces accuracy. A typical GPS receiver typically provides 18 meters to 90 meters accuracy, which is suitable for commercial use but not all applications, particularly in mission-critical situations where an accurate position is required.

1.5.2 Sources of GPS Position Error

The following are the major sources of GPS position errors.

1. **Satellite geometry and orbits:** Satellites drift slightly from their predicted orbits, contributing to errors. There is also a possibility of a slight shift of the orbits due to gravitational forces, but the resulting error is not more than 2 meters.

2. **Atmospheric interference:** The GPS signals must travel through the ionosphere where charged ions are formed, which delays transmission. Then,

there is refraction in the troposphere due to the concentration of water vapors, which affects the signal transmission.

3. **Receiver clock errors:** GPS receivers are equipped with quartz crystal clocks that are less stable than the atomic clock, which is used in satellites and causes errors.

4. **Calculation and round-off errors:** The receiver cannot simultaneously measure and compute the distance to each satellite. The computer at the receiver works with a fixed number of digits. It is, therefore, subject to calculation and rounding errors, these errors of the receiver sum up to approximately 1 meter.

5. **Multi-path distortions:** As the GPS signals arrive at the surface, they may be reflected by local obstructions before reaching the receiver's antenna. Therefore, the receiver receives the signal in the single path line and the delayed path, which gives duality, hence called multi-path error.

1.6 Methods

1.6.1 Overview of DGPS

A Differential Global Positioning System (DGPS) is the correction technique used to improve the quality of location data collected with GPS receivers. The United States Coast Guard (USCG) and Canadian Coast Guard (CCG) operate DGPS in the United States and Canada on long-wave radio frequencies between 285 KHz and 325 KHz in the vicinity of waterways and harbors [6].

DGPS uses the concept of a fixed GPS station as a reference point for the moving GPS. The reference station calculates the difference between its highly accurate known and GPS-derived positions and then transmits it locally using a shorter-range ground-based transmitter. The mobile GPS receiver applied the data to correct its position using the difference sent by the reference station and improved its accuracy using differential correction, as shown in Figure 3. The underlying premise of DGPS is that any two relatively close receivers exhibit similar atmospheric errors.

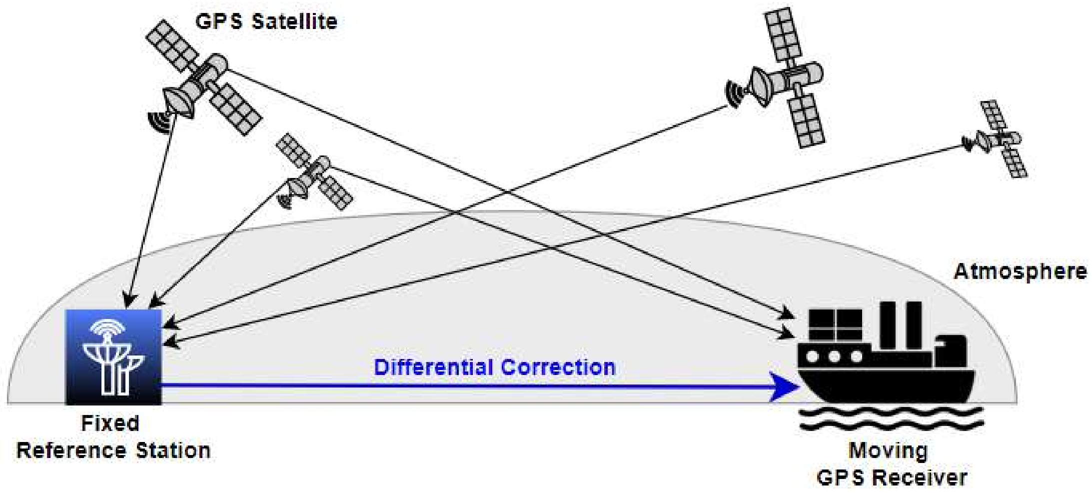

Figure 2: The Concept of Differential GPS in marine environment.

The differential corrections can be applied in two ways: (i) *real-time* (where GPS is in use) directly in the field via radio signals if the source is land-based or via satellite signal if it is satellite-based, and (ii) *post-processing*, in which corrections are done at a later time or while the rover uses a base GPS receiver that logs positions at a known location and a rover GPS receiver that collects position in the field.

1.6.2 Types of DGPS

There are different types of DGPS.

a. **SBAS (Space-Based Augmentation System)** – Correction messages are sent from geostationary satellites. E.g., EGNOS (European Geostationary Navigation Overlay Service) or WAA (Wide Area Augmentation System). These satellites are set at a fixed distance above the Earth's equator and follow the direction of the Earth's rotation. SBAS can have an accuracy of 2 meters or better. Some receivers can apply SBAS corrections with additional techniques to achieve sub-meter or better accuracy.

a. **RTCMv2 (Radio Technical Commission for Maritime Services)** – Correction messages are sent from a fixed base station, providing 40cm – 80cm accuracy.

b. **RTK (Real-Time Kinematic)** – Correction messages are sent from a fixed base station signal with an accuracy of <2cm or RTK-enabled units.

1.6.3 GPS v/s DGPS

The GPS provides a global instrument range, while the DGPS range is local. Table 3 covers the major differences between GPS and DGPS.

S. No	Summary	Value	
		GPS	**Differential GPS**
1.	Frequency	1.1 GHz to 1.5 GHz	As per requirement
2.	Coordinate system	Use WGS84 for time coordinate system	Local coordinate system
3.	Instruments Range	Global	Local
4.	Receivers	Only one	Two receivers

Table 3: Difference between GPS and differential GPS with respect to parameters.

Chapter 2

2.1 Design Components

The DGPS system is designed by integrating the hardware components listed in Table 4, along with the relevant specifications of each.

Required Components	Specifications
Arduino Mega 2560	8-bit microcontroller, 54 GPIO pins, 256KB flash Storage with 8KB SRAM, 4 Hardware Serial/ UART ports. 16MHz Clock Speed.
NEO-8M GPS Module	2.5m horizontal position Accuracy, navigation sensitivity (-163dBm), USB and UART interface, 9600 baud rates, commonly available with UART NMEA Protocol.
SD Card Reader/Module	Hardware SPI based SD card reader for data logging.
0' 96'' 'O' LED	Monochrome graphic display, 0.96 inch, 128x64 high resolution display.
APC220 Transceiver	Voltage: 5V Transmit power 20mW, open air range (800 m @9600 bps) Transmission range (1000m) Serial Transceiver Transmit distance up to 1000m (line of sight) @9600 bps, supports UART/TTL

Table 4: Hardware components and their specifications.

2.1.1 Hardware Components

The following is the description of the hardware components we used to develop the DGPS.

a) <u>Arduino Mega 2560</u>

A microcontroller board is based on ATmega2560. It carries analog and digital I/O pins, UARTs, a crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button, is shown in Figure 3. The board is compatible with most shields designed for the Uno and the other previous boards. It is easier to use, and the code is written in C++.

Figure 3: Arduino MEGA 2560 with labeled components.

The Arduino Mega 2560 technical specifications are listed in Table 5. The Arduino MEGA 2560 datasheet is added in Appendix B.

Summary	Value
Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Digital I/O Pins	54 (out of which 15 provide PWM output)
Analog Input Pins	16
Hardware serial/UART ports	4
DC current per I/O Pin	20 mA
DC current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz
Size (LxB)	101.53 mm x 53.3 mm
Weight	37g

Table 5: Technical specifications of Arduino MEGA 2560.

b) NEO-8M GPS Module

A GPS receiver with an in-built 25 x 25 x 4-millimeter (mm) ceramic antenna, which can provide a strong satellite search function, is shown in Figure 4. Unlike other GPS receivers, it can perform five location updates per second with a horizontal position accuracy of 2.5 meters. It can be easily interfaced with an Arduino microcontroller.

Figure 4: GPS module NEO-8M.

The technical specifications of the NEO-8M GPS module are listed in Table 6.

Summary	Value
Horizontal Position Accuracy	2.5m (GPS), 2.0m (SBAS)
Receiver Type	72 channels u-blox M8 engine
Navigation Update Rate	10Hz
Navigation Sensitivity	-163 dBm
Satellite System	GPS/QZSS, GLONASS, Galileo, BeiDuo
Communication Protocol	NMEA, UBX Binary, RTCM
Interface	UART, USB, SPI
Analog Input Pins	24
Power Supply	2.7V – 3.6V
Operational Limit	Altitude = 50,000m, Velocity = 500m/s
Default Baud Rate	9600

Table 6: Technical specifications of NEO8M GPS module.

c) <u>0.96 OLED</u>

The OLED display is a small 3cm diagonal screen that displays latitude and longitude to the viewer. The display consists of 128x64 OLED pixels, individually controlled by the built-in SSD1306 chip, as shown in Figure 5. We initially used it to display the coordinates and error values, which were then displayed on the web application running on the laptop.

Figure 5: OLED 0.9 display screen.

d) APC 220Transceiver

A radio module that provides wireless data communication**.** It eliminates the need for packetizing and data encoding as it integrates a high-speed embedded microprocessor and high-performance IC that creates a transparent UART/TTL interface, as shown in Figure 6. It has a transmission range of up to 1000m in line of sight (LoS) at 9600bps.

Figure 6: APC 220 wireless communication module.

The APC220 transceiver technical specifications are listed in Table 7.

Summary	Value
Frequency	431 MHz to 478 MHz
Power Supply	3.3V - 5.5V
Current	<25-35mA
Interface	UART/TTL
Range	1200m LoS (1200 bps)
Baud rate	1200-19200 bps
Size	37mm x 17 mm x 6.6 mm

Table 7: Technical specifications of APC220 module.

2.1.2 Software Components

Following are the software tools/simulators which are used in the project.

a) <u>Arduino IDE</u>

The Arduino Integrated Development Environment (IDE) provides a text editor, a message area, a text console, and toolbars for the commonly used functions and menus, as shown in Figure 7. It connects to the Arduino hardware to upload programs and communicate with them. It uses a compiler that supports both C and C++. However, it can also be used with Python or any other high-level programming language.

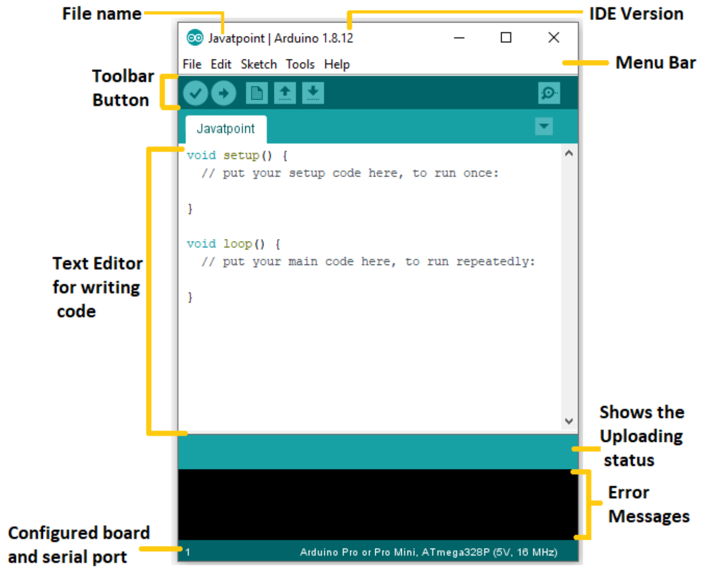

Figure 7: Arduino IDE interface.

b) <u>U-BLOX U-CENTER 2</u>

U-center is GNSS evaluation software compatible with U-blox technologies. The U-center 2 is the next-generation software for asset tracking and wearable devices. It offers a personalized workspace and adaptive window controls. The log player provides message and time-based navigation with adjustable playback speed and import of U-center log files. The interface of U-blox is shown in Figure 8.

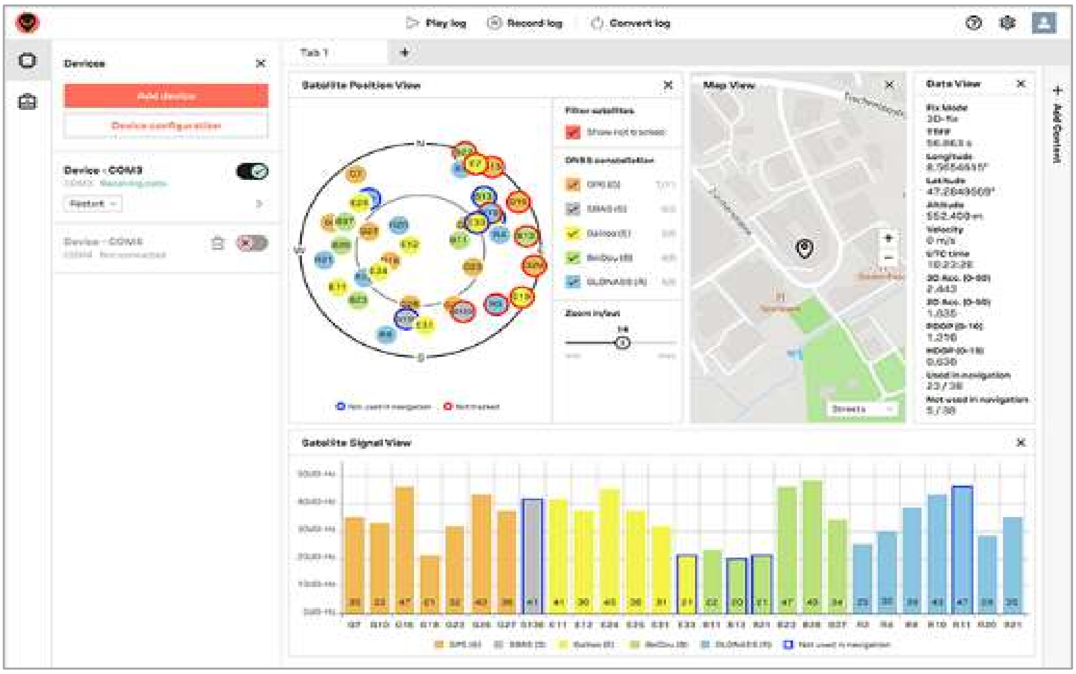

Figure 8: U-box U-center interface.

c) Google Earth

Google Earth is a geo-browser that accesses satellite and aerial imagery, topography, ocean bathymetry, and other geographic data over the internet. It renders a 3D representation of Earth based primarily on satellite imagery, as shown in Figure 9. The Google Earth Pro desktop version offers numerous features that are useful in educational settings and offers additional capabilities such as higher resolution printing and saving of images and the ability to open ESRI (Environmental Systems Research Institute) shape files, which is a vector data file format commonly used for geographical analysis.

Figure 9: KHA Hockey Complex view on Google Earth.

d) <u>FIGMA</u>

It is a browser-based collaborative user interface design tool used for interface designing, with additional offline features enabled by desktop applications. It creates, shares, and tests designs for websites, mobile apps, and other digital products and experiences. The vibrant and interactive prototypes can be created, as shown in Figure 10. In this project, we used it to design the web portal to show the tracking of moving stations and the related statistics.

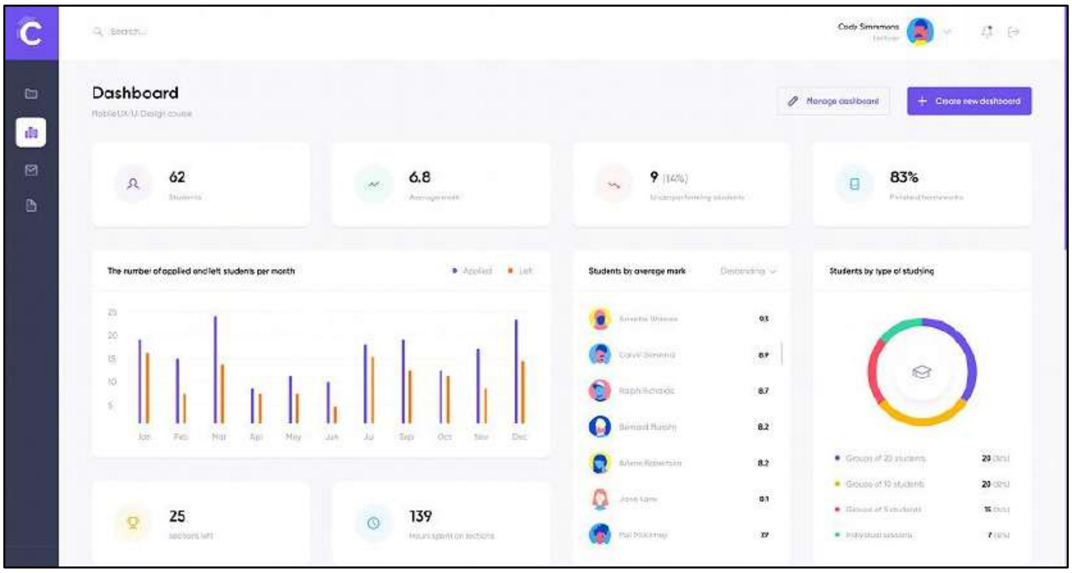

Figure 10: Sample dashboard design created using Figma.

Chapter 3

The methodology and results are not provided here as the project is not presented in the university yet. Therefore, due to copyrights we have not added the details here. However, the details can be provided on request after the approval from the project stakeholders.

The prototype of our project is shown in Figure 11

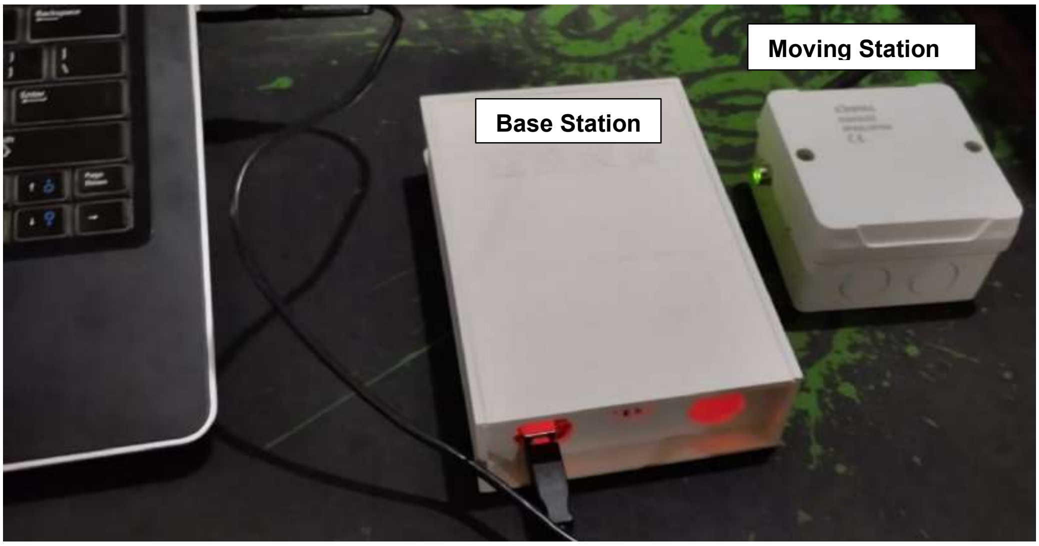

Figure 11: Differential GPS prototype.

Chapter 4

4.1 Results & Discussion

The desired results have been achieved in which the designed DGPS system is able to achieve the location accuracy of less than 1 meter.

Following are the activities undertaken, which are divided into different phases, shown in Figure 12. The PERT activity estimation timeline (in weeks) is shown in Table 8.

Figure 12: Project design and development phases.

Activity	Optimistic (a)	Most Likely (m)	Pessimistic (b)	Expected (Te)
Phase 1 (A)	3	2	4	2.5
Phase 2 (B)	9	7	10	8
Phase 3 (C)	9	7	11	8
Phase 4 (D)	3	2	3.5	2.5
Phase 5 (E)	1.5	1	2	1

Table 8: PERT Activity Time estimate table.

Chapter 5

5.1 Summary and Future work

The project consists of five main phases, i.e., research, design, development, evaluation, and preparation of reports/publications. Extensive research, evaluation, and design of the DGPS prototype has yielded results that substantially exceed the manufacturer rated specifications and prove the benefits of DGPS for tracking the marine moving object. The purpose of the project is to improve the accuracy of GPS accuracy in longitude and latitude coordinates. The average accuracy of GPS is about 10-15 meters, sometimes, more precise, but it depends on the signal propagation factors. In altitude, the accuracy is reduced to 50% regarding the longitude and latitude obtained. Therefore, we designed a Differential GPS system to overcome the deficiency in GPS system and increase its accuracy upto 1 meter. The DGPS use differential corrections to improve the accuracy of moving station, assists in location tracking in correspondence with the base station which is the control/monitoring station. The base station can send alert through radio communication to the moving boats and notify the user about the hazardous situation or location.

In future, multiple moving stations can help to track their locations in case if not in contact with base station as the radio communication is affected by the environmental factors. The transmission range can be increased by using long range transceivers and the protocol can be designed to increase the communication range.

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