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IoT-based Landsat 9 Satellite Tracking System

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Abstract: In today's world, the growth of Internet of Things (IoT) applications in our everyday lives increases. Smart devices, sensor technologies, and the internet enable seamless data gathering, communication, and processing across a variety of applications in the digital and physical worlds. The aim is to track the location of Landsat 9 satellite and get the captured images from the satellite and view in IoT application. Blynk. The satellite tracking system links with an ESP32 microcontroller to deliver data to Blynk for additional cloud-based services and data analysis. Two-Line Element (TLE) data is given to any Earth-orbiting objects and a model called Simplified General Perturbations 4 (SGP4) is used with TLE data to predict and simulate the satellite position at any given point in time. From the results, since the orbital inclination and height of the Landsat 9 satellite are approximately 98.2° and 705 km, respectively, the maximum values of the latitude and altitude are slightly above 80° and less than 720 km, respectively. The images captured by the satellite show the changes of the Earth's land over time. The proposed system operates effectively in a setting with constrained resources and is lightweight and can be used anywhere.

Keywords: Internet of Things, Landsat 9, TLE, SGP4

1. Introduction

Satellites are used for many things such as providing an image of the Earth and many organizations can use the data recorded to gain information to make people safer and make our lives more efficient. The first Landsat satellite was launched in 1967, more than 50 years ago. The Landsat satellite monitors how land is used on Earth and takes pictures of how land is changing as a result of urbanization, climate change, and other natural and human-caused changes [1]. After gathering earth observation data for well over four decades, since the launch of Landsat-1 in 1972, the Landsat programme is getting more complex and active [2].

The research of IoT based satellite tracking system is to identify position of Landsat 9 satellite which is the newest Landsat satellite launched in 2021. The interface to access the data in websites is complex and not user friendly to someone who wants to learn about satellite information accessibility of the satellite tracking system is the cost. The majority of traditional satellite locating applications are

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high value due to their high cost and general impracticality for amateurs [3]. A low cost satellite tracking system for LEO satellite that uses a directional antenna to communicate and obtain data such as weather data and to be decoded by the developed system [4]. Another satellite tracking system that designed for ground station that tracked satellite using frequencies from the Yagi antenna to measure the accuracy of the satellite movement and can also obtain data to be decoded by the system [5].

Technology nowadays focuses on the IoT for easier and more accessible to obtaining information. A satellite tracking system that uses IoT for real time that can track the location of extraterrestrial objects in space and only capture image of the tracked objects by using Raspberry Pi [6]. This work aims to determine and monitor the location of the satellite as well as obtain images captured by the satellite through Blynk IoT platform. This IoT-based system's low cost is achieved by using consumer-grade devices that are easily portable and battery-powered.

2. Materials and Methods

In this work, the workflow is being implemented in accordance with the objectives. The flowchart is depicted in Figure 1. The processes involved in developing the system are elaborated in the following sections.

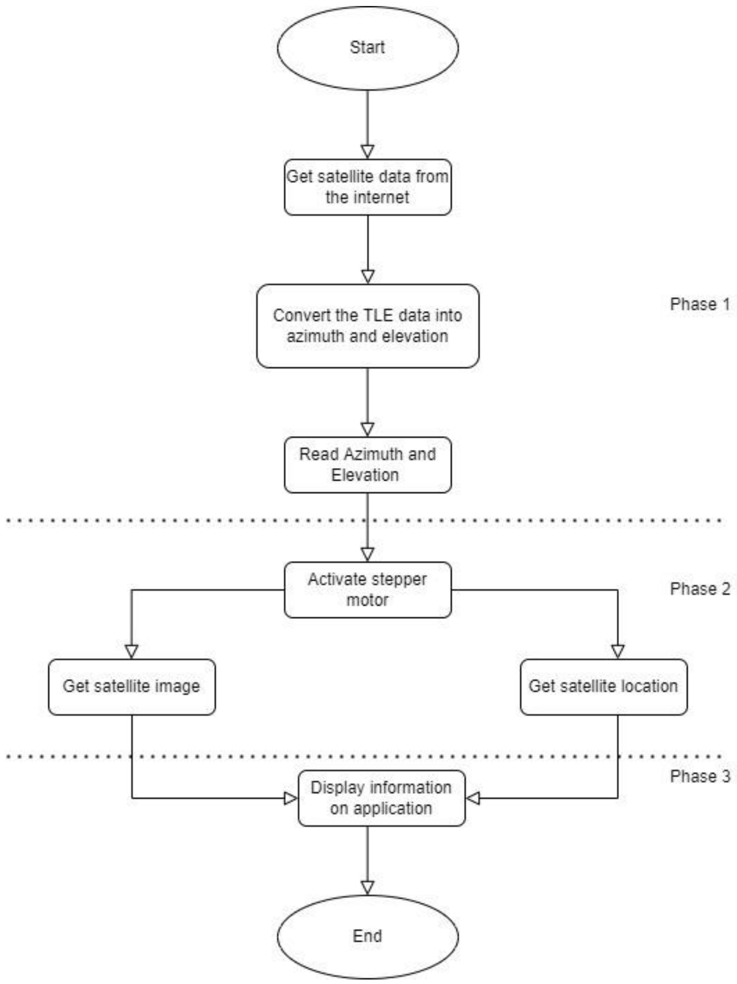

Figure 1: Flowchart of the work

2.1 Data Acquisition and Processing

The Landsat 9 satellite data is obtained from Celestrak website (https://celestrak.com). Earth-orbiting objects has a data called TLE which is a data format encoding a list of orbital elements of an

Earth-orbiting object for a given point in time. The layout of the website and TLE data of the Landsat 9 are shown in Figure 2 and 3, respectively.

Figure 2: Celestrak website satellite catalog

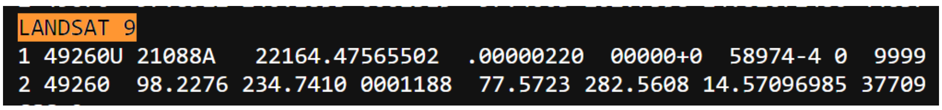

Figure 3: Landsat 9 TLE data

To obtain the satellite location obtained from the website, a model called Simplified General Perturbations 4 (SGP4) used for simulating earth-orbiting objects. The primary purpose of this would be to obtain a more accurate TLE from independent data [7]. Arduino library has a SGP4 coding that can be downloaded and used with the TLE data to predict the path of the satellite.

2.2 Satellite tracking process

The satellite tracking system consists of ESP32 microcontroller that controls the system with 28BYJ-48 stepper motor and ULN2003 motor driver. The circuit design for the satellite tracking system are shown in Figure 4.

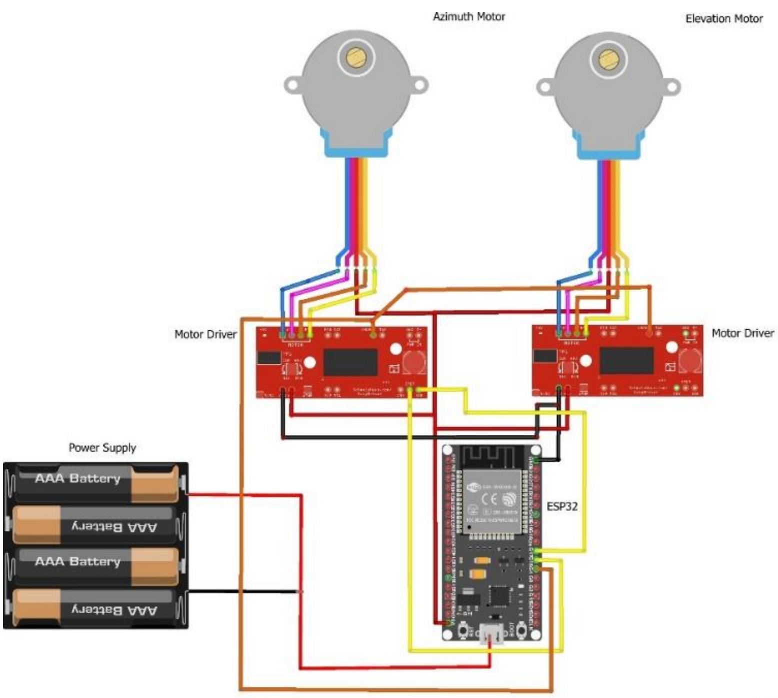

Figure 4: Circuit design of the satellite tracking system

2.3 IoT and application development

Blynk cloud server is utilized as the IoT platform for this work. The created coding is uploaded to the ESP-32 to track the satellite location and will be visualized through the Blynk app. The satellite images are obtained from EarthExplorer website (https://earthexplorer.usgs.gov) which provide satellite images, aerial photographs, and cartographic products through geological survey. Figure 5 and 6 shows the EarthExplorer website and mobile interface for Blynk, respectively.

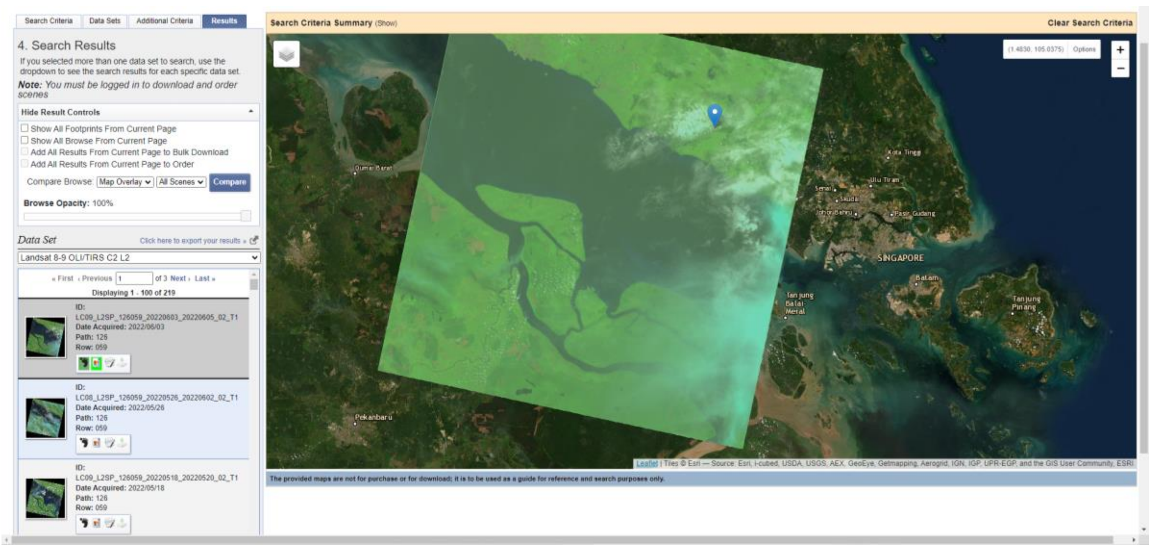

Figure 5: EarthExplorer website layout

Figure 6: Blynk application mobile interface

3. Results and Discussion

The satellite tracking system prototype consists of two stepper motors that move according to the azimuth and elevation data of Landsat 9 and are powered by a power bank. The elevation motor has a wire that points to the location of the satellite. Figure 7 shows the side and aerial view of the prototype of the satellite tracking system.

Figure 7: Side view and aerial view of the satellite tracking system prototype

3.1 Results

For the result, the result that are obtained is the SGP4 coding that is used to track the satellite that has been uploaded to the ESP-32 from the Arduino IDE. The prototype of the system is unable to locate the satellite due to complication in the coding of the system resulting the motor cannot move towards the satellite coordinates. However, the visual map and data of the satellite position can be monitored in the Blynk application. The results of the tracking are monitored from the Blynk IoT application as shown in Figure 8.

The satellite location data such as longitude, latitude, altitude, azimuth, elevation, and distance are shown on the app. The coordinates are updated every one second, and the following information is periodically fed to Blynk. The location of the satellite can be seen in Figure 8, as displayed on the Blynk app. In this figure, the satellite can be seen in the South Pacific Ocean between New Zealand and Antarctica. But, due to the limitation of the map widget in Blynk, the widget does not have a tracking line and cannot display its previous path and only the current path is shown.

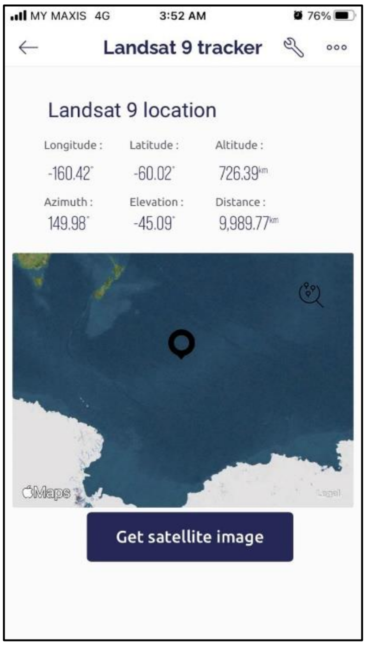

Figure 8: Satellite location data in Blynk IoT application

A plot of latitude and longitude of the satellite over a 1-day period can be seen in Figure 9 and Figure 10. From the figures, it can be seen that the latitude has a maximum value of slightly above 80°, and altitude below 720 km which is expected since the orbital inclination and altitude of Landsat 9 satellite is around 98.2° and 705 km respectively [8].

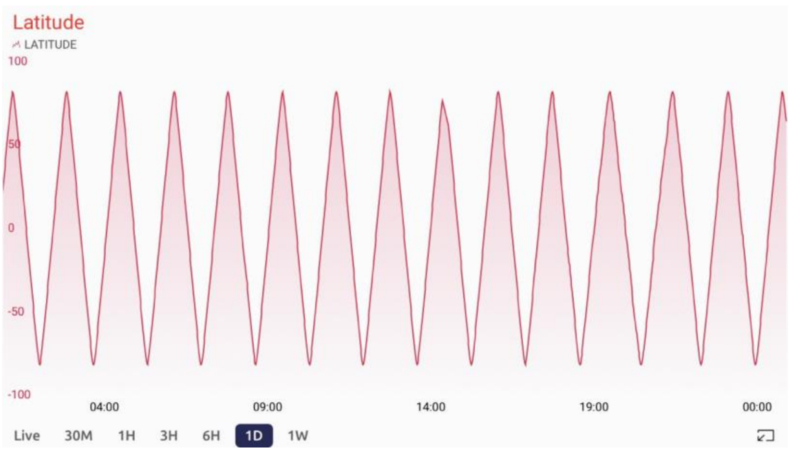

Figure 9: Landsat 9 Latitude over 1-day period

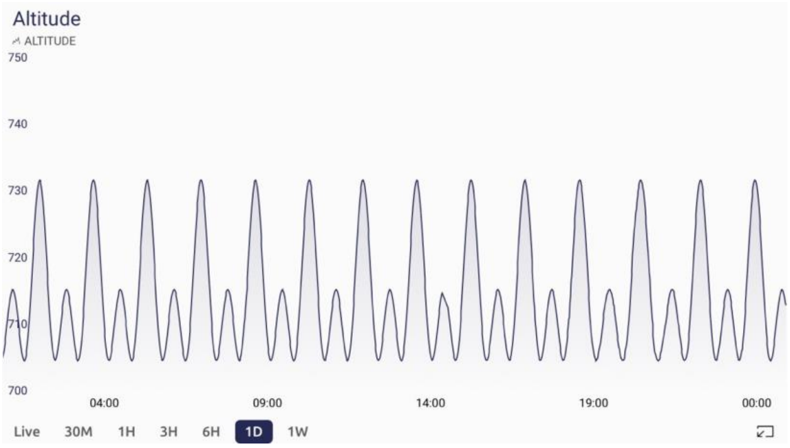

Figure 10: Landsat 9 Altitude over a 1-day period

Figure 11 shows the longitude of Landsat 9 satellite over a 1-hour period. The spike on the data of the longitude of the satellite shows that the satellite passed the prime meridian which is 0° and continue passing through the eastern or southern hemisphere which shows the positive and negative reading since the satellite orbit the earth every 99 minutes. The distance over a 1-day period from Figure 12 is the distance between the satellite and the device and the data showed that the satellite is closest to the device is about every 10 hours.

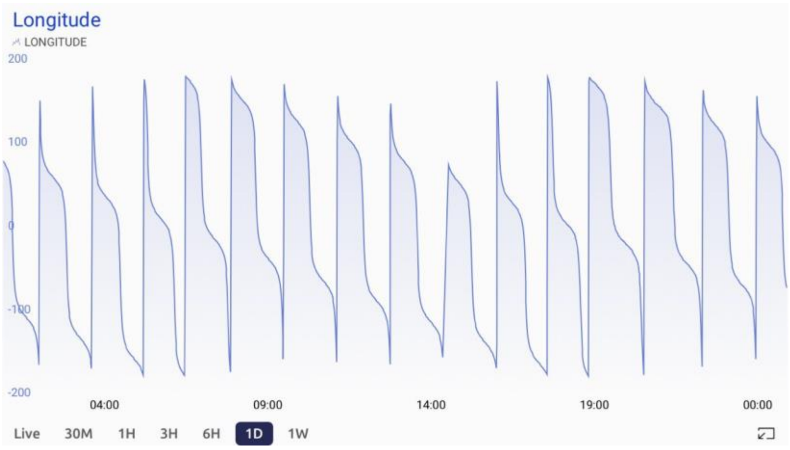

Figure 11: Landsat 9 Longitude over a 1-day period

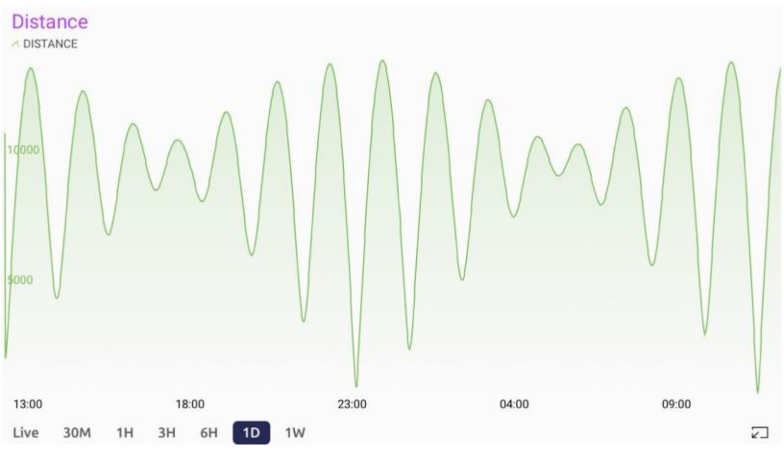

Figure 12: Landsat 9 Distance over a 1-day period

The azimuth data of the satellite is obtained relative to the device location which is in the northern hemisphere. The data shows from 0° to 360°, which is when the satellite has orbited the earth. But when the satellite passes through above the device, the azimuth becomes negative as the satellite passes the southern hemisphere. The elevation of the satellite at each point is relative to the device's starting point which is 6°. The positive elevation is when the satellite is above the starting altitude, negative elevation means that the satellite is below the device's starting altitude. The satellite azimuth and elevation are shown in Figure 13 and Figure 14, respectively.

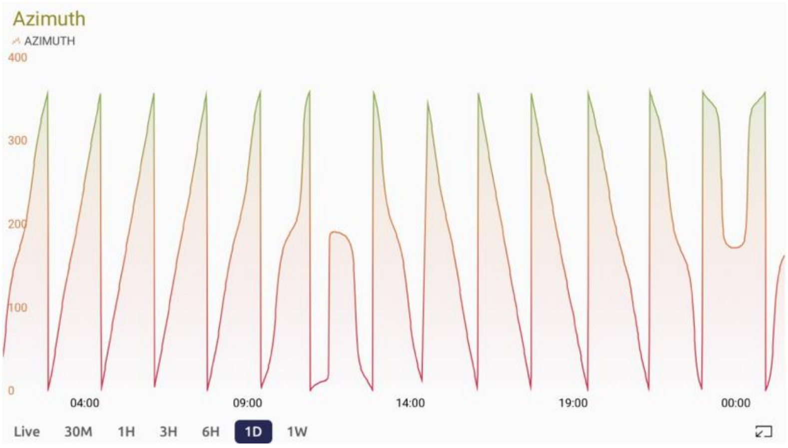

Figure 13: Landsat 9 Azimuth over a 1-day period

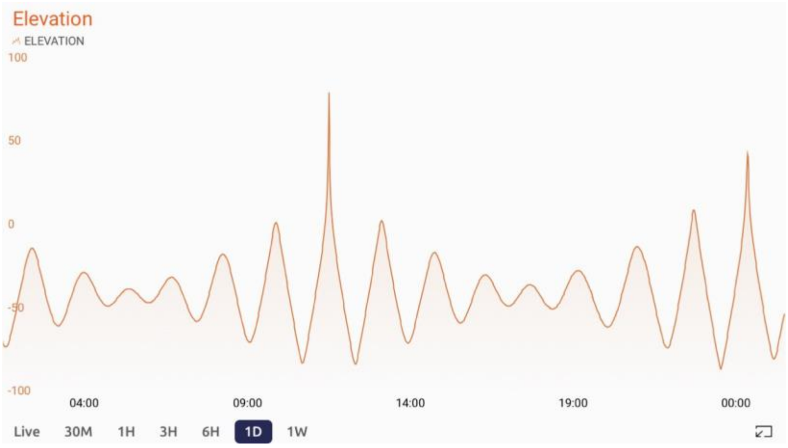

Figure 14: Landsat 9 Elevation over a 1-day period

The images from the satellite can be searched from the button below the map shown in Figure 8. It will be directed to https://earthexplorer.usgs.gov/ where images from the Landsat satellite can be obtained. From the website, to obtain the images from the satellite, information such as coordinates are inserted on the search criteria or pointed at the map provided for easier search. The images obtained are from 13th January 2023 and 10th January 2022. The captured images from Landsat are shown in Figure 15 and 16, respectively.

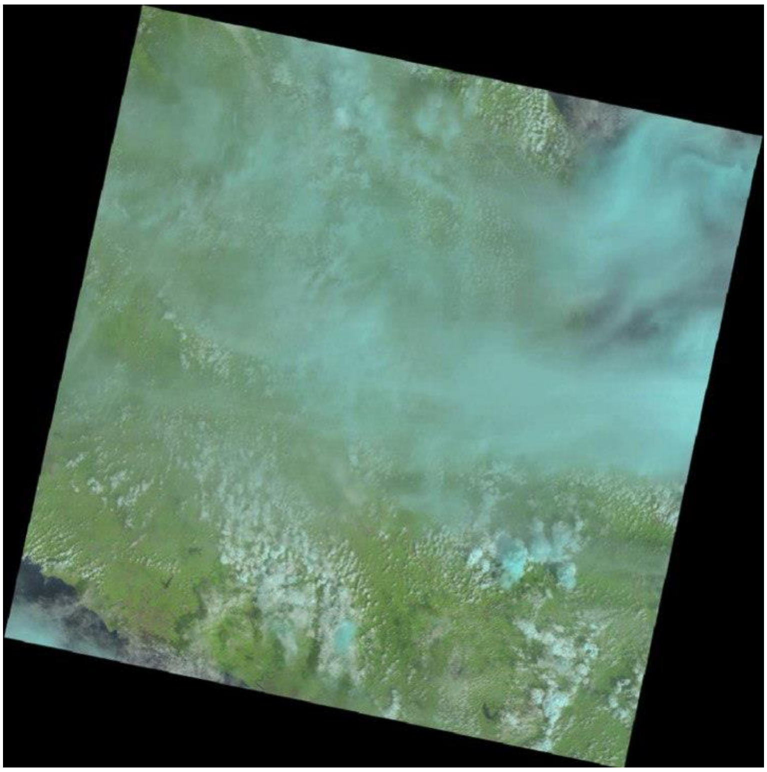

Figure 15: Landsat 9 images taken on 13th January 2023

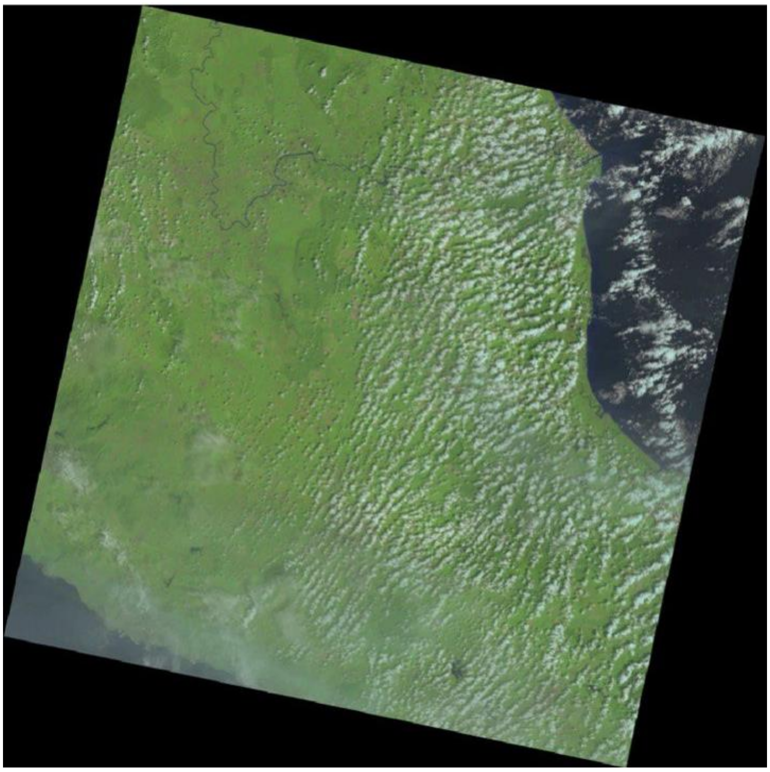

Figure 16: Landsat 9 images taken on 10th January 2022

From the images, it shows difference between the terrain and vegetation of the land in Malaysia that ranges between Melaka, Johor, Negeri Sembilan, and Pahang. The blue smear on the images indicates a cloud that affected the quality of captured image.

4. Conclusion

The Landsat 9 location has been successfully tracked using the SGP4 along with the satellite TLE data but with some failure with the prototype. The satellite data can be viewed in the Blynk application and analysis has been made to monitor the location of the satellite position. Next, the past and current images captured by the satellite can also be viewed through the application. For future work, by developing an application integrating with Blynk server can increase interactivity with the system for easier understanding with addition of multiple satellite that can be tracked.

Acknowledgement

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