Data Visualization Tools and Software
ESE Dashboard Project

Title: Visualization of Performance Indicators for Unmanned Aerial Vehicle

1. Objectives

An Unmanned Aerial Vehicle (UAV) dashboard's performance indicators are meant to give users an accurate and current overview of the UAV's operational performance and success in its mission [1]. These markers satisfy a number of important functions:

- Operational Efficiency: Performance metrics in determining the UAV's operational efficiency To make sure that missions are being completed as efficiently as possible, this involves tracking how fuel, battery life, and flying time are used [2].

- Maintenance and Predictive Analysis: By keeping a regular eye on the UAV's performance indicators, maintenance requirements can be predicted. By becoming proactive, we can reduce delay and ensure that the UAV is always prepared for a mission [3].

- Safety and Reliability: It's imperative to keep an eye on measurements related to the safety and health condition of UAVs. Data on sensor health, redundancy, system integrity, and general dependability can be included in order to reduce the possibility of accidents and assure safe operations [4].

2. Description of the dataset

The dataset used is an extensive set of data produced in a virtual environment utilizing QGroundControl, PX4 Autopilot, and Gazebo. Development and research efforts in the fields of autonomous systems and unmanned aerial vehicles (UAVs) could benefit immensely from this information. It offers a computer-generated simulation of actual UAV activities.

2.1 Use of the dataset

This dataset can be used by researchers and developers for:

- The development and evaluation of algorithms for UAV sensing, control, and mission scheduling
- Training machine learning models to perform tasks such as path planning, SLAM, and object detection.
- Analyzing and improving resilience of systems and UAV navigation.

2.2 Content of Data

The following categories of data are present in the dataset:

Sensor data: IMU readings, GPS coordinates, lidar scans, and environmental sensor data.

Control commands: throttle, yaw, pitch, and roll commands sent to the UAV.

Flight logs: detailed records of UAV behavior, navigation, and system performance.

2.3 Tables Description

The data that we are using consists of four tables.

Table Name: Control commands

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Timestamp	roll	pitch	heading	rollRate	pitchRate	yawRate	groundSpeed	climbRate	throttlePct	setpoint.roll	setpoint.pitch	setpoint.yaw	setpoint.rollRate	setpoint.pitchRate	setpoint.yawRate	
2	2023-10-11 4:11:21	-4.4	-31.2	359	-0.5	-0.6	-0.2	11.2	0	42	-4.5	-31.6	359.9	-0.5	-3.2	-0.2	
3	2023-10-11 4:11:22	-4.5	-31.1	359	-0.4	-0.4	0.3	11.2	0	41	-4.7	-31	359.9	-1	-3.7	-0.1	
4	2023-10-11 4:11:23	-4.7	-31	359	0	0.2	0.1	11.2	0	41	-4.7	-31.4	359.9	-0.6	5.5	0.1	
5	2023-10-11 4:11:24	-4.8	-31.1	359	0.3	1	-0.4	11.2	0	41	-4.9	-31.4	359.9	-1.2	5.5	0.2	
6	2023-10-11 4:11:25	-4.9	-27.3	359	-0.8	24.7	0.9	11.1	0	41	-5.3	-24.7	0.1	-2.6	25.7	1.4	
7	2023-10-11 4:11:26	-4.9	-29.5	0	0.3	3.5	1.8	10.1	-0.1	42	-5.2	-27.8	0.5	-2	19.3	1.4	
8	2023-10-11 4:11:27	-5	-32.5	1	0.7	-23.9	-2.2	10	0	43	-4.4	-33.3	0.4	1.5	-0.4	-2.2	
9	2023-10-11 4:11:28	-4.5	-25.2	0	-1	18.1	1.1	10.4	-0.1	40	-4.6	-23	0.8	-0.3	19.6	1.5	
10	2023-10-11 4:11:29	-4.8	-14.8	0	-0.7	5.6	1.3	9.7	-0.2	40	-5	-12.9	0.9	-0.3	17.6	2.4	

Column Name	Description
Timestamp	Timestamp refers to a time reference associated with data that the drone collects, transfers, or transfers while in flight.
roll	The rotation of the drone along the x-axis is called roll.
pitch	The rotation of the drone along the y-axis is called pitch.
heading	Heading used to determine the direction of Magnetic North.

rollRate	Rollrate refers to the rate at which the UAV is rotating around its longitudinal axis
pitchRate	Pitchrate refers to the angular velocity or rotational speed at which the UAV is rotating around its lateral axis.
yawRate	Yawrate refers to the rate of rotation of the UAV around its vertical axis.
groundSpeed	Groundspeed refers to the horizontal speed at which the aircraft is moving over. the ground
climbRate	Climbrate refers to the rate at which the UAV is ascending or descending vertically through the air.
throttlePct	ThrottlePct refers to the throttle percentage, or throttle setting.
setpoint.roll	Setpoint.roll refers to a reference value that defines the desired or target roll angle for the UAV.
setpoint.pitch	Setpoint.pitch refers to the desired or target pitch angle that the UAV should maintain during its flight.
setpoint.yaw	Setpoint.yaw refers to a specific value that represents the desired or target yaw angle for the UAV.
setpoint.rollRate	Setpoint.rollRate typically refers to a control command or input used to set the desired roll rate of the UAV.
setpoint.pitchRate	Setpoint.pitchRate refers to a specific control parameter used in the UAV's flight control system.
setpoint.yawRate	Setpoint.yawRate refers to a control parameter used to specify the desired yaw rate for the UAV.

Table Name: Sensor data

	A	B	C	D	E	F	G	H	I	J	K	L
1	Timestamp	altitudeRelative	altitudeAMSL	altitudeTuning	flightDistance	flightTime	distanceToHome	missionItemIndex	headingToNextWP	headingToHome	distanceToGCS	
2	2023-10-11 4:11:21	164.1	1766.4	0.004	121	0:00:00	438	17	--.--	149	44228884.6	
3	2023-10-11 4:11:22	164.1	1766.4	0	140.7	0:00:06	456.3	17	--.--	150	44228864.4	
4	2023-10-11 4:11:23	164.1	1766.4	0	147.3	0:00:07	462.3	17	--.--	151	44228857.9	
5	2023-10-11 4:11:24	164.1	1766.4	-0.005	160.5	0:00:08	473.2	17	--.--	151	44228846	
6	2023-10-11 4:11:25	164.1	1766.4	-0.004	173.8	0:00:09	483	17	--.--	152	44228835.4	
7	2023-10-11 4:11:26	163.9	1766.3	-0.049	180.3	0:00:10	491.4	17	--.--	152	44228826.4	
8	2023-10-11 4:11:27	163.9	1766.3	-0.07	193.8	0:00:11	501.8	18	0	153	44228815.3	
9	2023-10-11 4:11:28	163.9	1766.2	-0.057	200.4	0:00:12	510.3	18	0	153	44228806.1	
10	2023-10-11 4:11:29	163.9	1766.2	-0.077	207.1	0:00:13	516.4	18	0	154	44228799.7	

Column Name	Description
Timestamp	Timestamp refers to a time reference associated with data that the drone collects, transfers, or transfers while in flight.
altitudeRelative	Relative altitude refers to the altitude or height of the UAV above its starting or reference point.
altitudeAMSL	AMSL (above mean sea level) altitude refers to the height or elevation of the UAV relative to a standardized reference point, which is typically mean sea level.
altitudeTuning	Altitude tuning refers to the process of adjusting and fine-tuning the UAV's altitude control system to achieve the desired performance and stability in maintaining a specific altitude during flight.
flightDistance	Flight distance typically refers to the total distance that a UAV travels during its flight mission.
flightTime	Flight time refers to the duration for which the drone can remain airborne on a single battery charge or fuel load.
distanceToHome	Distance to Home refers to the measurement of the straight-line distance between the current location of the UAV and its takeoff point
missionItemIndex	MissionItemIndex typically refers to an index or position within a list or array of mission items.
headingToNextWP	HeadingToNextWP typically refers to the heading or direction that the UAV needs to follow in order to reach its next waypoint (WP).
headingToHome	HeadingToHome refers to the direction or heading that the UAV is set to follow in order to return to its home point or the location from which it took off.
distanceToGCS	DistanceToGCS refers to the distance from the UAV to the Ground Control Station (GCS).

Table Name: Local Position

	A	B	C	D	E	F	G	H	I	J	K	L
1	Timestamp	localPosition.x	localPosition.y	localPosition.z	localPosition.vx	localPosition.vy	localPosition.vz	localPositionSetpoint.x	localPositionSetpoint.y	localPositionSetpoint.z	localPositionSetpoint.vx	localPositionSetp
2	2023-10-11 4:11:21	374.1	-227.9	-164.1	11.2	0	0	374.3	-227.8	-164	11.3	
3	2023-10-11 4:11:22	395.2	-228	-164.1	11.2	0	0	395.3	-227.9	-164	11.2	
4	2023-10-11 4:11:23	402.1	-228	-164.1	11.2	0	0	402.3	-227.9	-164	11.3	
5	2023-10-11 4:11:24	414.6	-228	-164.1	11.2	0	0	414.7	-228	-164	11.3	
6	2023-10-11 4:11:25	425.7	-228.1	-164.1	11	0	0.1	425.8	-228	-164	10.8	
7	2023-10-11 4:11:26	435.2	-228.2	-163.9	10.1	0	0.1	435	-228	-164	9.9	
8	2023-10-11 4:11:27	446.8	-228.3	-163.9	10.2	0.1	-0.1	446.6	-228.1	-164	10.4	
9	2023-10-11 4:11:28	456.3	-228.4	-163.9	10.4	0.2	0.1	456.3	-228.1	-164	10.4	
10	2023-10-11 4:11:29	463.1	-228.4	-163.7	8.7	0.2	0.4	462.9	-228.1	-164	8	

Column Name	Description
Timestamp	Timestamp refers to a time reference associated with data that the drone collects, transfers, or transfers while in flight.
localPosition.x	localPosition.x refers to the UAV's position along the local x-axis within a 3D coordinate system.
localPosition.y	localPosition.x refers to the UAV's position along the local y-axis within a 3D coordinate system.
localPosition.z	localPosition.x refers to the UAV's position along the local z-axis within a 3D coordinate system.
localPosition.vx	localPosition.vx parameter represents the velocity of the UAV in the forward or north direction (along the x-axis)
localPosition.vy	localPosition.vy represents the velocity of the UAV in the lateral or side-to-side direction (along the y-axis)
localPosition.vz	localPosition.vz represents the vertical velocity of the UAV, indicating how fast the UAV is ascending or descending
localPositionSetpoint.x	localPositionSetpoint.x refers to a variable or parameter that represents the setpoint position of the UAV along the X-axis in a local coordinate system.
localPositionSetpoint.y	localPositionSetpoint.y refers to a component of a setpoint position that the UAV's flight controller uses to control the aircraft's movement in the lateral (side-to-side) direction

localPositionSetpoint.z	localPositionSetpoint.z refers to a parameter that represents the desired or setpoint altitude (or vertical position) for the UAV in its local coordinate system.
localPositionSetpoint.vx	localPositionSetpoint.vx refers to a parameter that represents the desired velocity in the vehicle's local frame of reference.
localPositionSetpoint.vy	localPositionSetpoint.vx typically refers to a parameter used to control the desired velocity in the vehicle's local coordinate system
localPositionSetpoint.vz	localPositionSetpoint.vz typically refers to a specific parameter that represents the desired vertical (z-axis) velocity setpoint for the UAV.

Table Name: ESC Status

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Timestamp	escStatus.rpm1	escStatus.rpm2	escStatus.rpm3	escStatus.rpm4	escStatus.current1	escStatus.current2	escStatus.current3	escStatus.current4	escStatus.voltage1	escStatus.voltage2	escStatus.voltage3	escStatus.
2	2023-10-11 4:11:21	2646	2346	1632	3360	7.615	6.865	5.08	9.4	15.3	15.3	15.3	
3	2023-10-11 4:11:22	2634	2340	1638	3342	7.585	6.85	5.095	9.355	15.3	15.3	15.3	
4	2023-10-11 4:11:23	2628	2346	1632	3342	7.57	6.865	5.08	9.355	15.3	15.3	15.3	
5	2023-10-11 4:11:24	2628	2346	1632	3342	7.57	6.865	5.08	9.355	15.3	15.3	15.3	
6	2023-10-11 4:11:25	2646	2340	1620	3366	7.615	6.85	5.05	9.415	15.3	15.3	15.3	
7	2023-10-11 4:11:26	2712	2382	1764	3330	7.78	6.955	5.41	9.325	15.3	15.3	15.3	
8	2023-10-11 4:11:27	2712	2382	1764	3330	7.78	6.955	5.41	9.325	15.3	15.3	15.3	
9	2023-10-11 4:11:28	2694	2346	1788	3252	7.735	6.865	5.47	9.13	15.3	15.3	15.3	
10	2023-10-11 4:11:29	2694	2346	1788	3252	7.735	6.865	5.47	9.13	15.3	15.3	15.3	

Column Name	**Description**
Timestamp	Timestamp refers to a time reference associated with data that the drone collects, transfers, or transfers while in flight.
escStatus.rpm1	escStatus.rpm1 refers to the RPM value of the motor connected to Electronic Speed Controller channel 1 (ESC1).
escStatus.rpm2	escStatus.rpm1 refers to the RPM value of the motor connected to Electronic Speed Controller channel 2 (ESC2).
escStatus.rpm3	escStatus.rpm1 refers to the RPM value of the motor connected to Electronic Speed Controller Channel 3 (ESC3).
escStatus.rpm4	escStatus.rpm1 refers to the RPM value of the motor connected to Electronic Speed Controller channel 4 (ESC4).

escStatus.current1	escStatus.current1 refers to the current being drawn by the electric motor connected to the first Electronic Speed Controller (ESC1) in the UAV.
escStatus.current2	escStatus.current1 refers to the current being drawn by the electric motor connected to the second Electronic Speed Controller (ESC2) in the UAV.
escStatus.current3	escStatus.current1 refers to the current being drawn by the electric motor connected to the third Electronic Speed Controller (ESC3) in the UAV.
escStatus.current4	escStatus.current4 refers to the current being drawn by the electric motor connected to the fourth Electronic Speed Controller (ESC4) in the UAV.
escStatus.voltage1	escStatus.voltage1 in the context of a UAV refers to the voltage measurement associated with the Electronic Speed Controller (ESC) of the first motor
escStatus.voltage2	escStatus.voltage2 in the context of a UAV refers to the voltage measurement associated with the Electronic Speed Controller (ESC) of the second motor
escStatus.voltage3	escStatus.voltage3 in the context of a UAV refers to the voltage measurement associated with the Electronic Speed Controller (ESC) of the third motor
escStatus.voltage4	escStatus.voltage4 in the context of a UAV refers to the voltage measurement associated with the Electronic Speed Controller (ESC) of the fourth motor

2.3 Type of file

Log Data Files: PX4 Autopilot and QGroundControl create log files with the extension ".ulg". These log files include complete flight data, including system status, control inputs, and sensor readings.

3. Measures/KPIs

Table : Control commands

1. Total Pitch: Sum of all pitch values.
   DAX Function: SUM ([pitch])

2. Average Ground Speed: Average ground speed across all timestamps
   DAX Function: AVERAGE ([groundSpeed])

3. Maximum Climb Rate: The maximum climb rate observed in the dataset
   DAX Function: MAX([climbRate])

4. Total Throttle Percentage: Sum of all throttle percentage values.
   DAX Function: SUM ([throttlePct])

5. Measure: Average values of Pitch angles
   Pitch AVERAGE = AVERAGE('Control commands'[pitch])

6. Measure: Average values of Roll angles
   Roll AVERAGE = AVERAGE('Control commands'[roll])

7. Measure: Average values of Heading angles
   Heading AVERAGE = AVERAGE('Control commands'[heading])

Table : Sensor data

1. Total Flight Time: This KPI represents the cumulative time spent on all drone flights.
   DAX Function: SUM (dataset[flightTime])

2. Average Altitude Relative: This KPI gives you the average relative altitude of all flights
   DAX Function: AVERAGE(dataset[altitudeRelative])

3. Total Distance Flown: This measures the total distance covered by the drone during all flights
   DAX Function: SUM (dataset[flightDistance])

4. Average Distance to Home: This KPI shows the average distance from the drone to the home point during the flights.
   DAX Function: AVERAGE(dataset[distanceToHome])

5. Maximum Altitude AMSL: The highest altitude Above Mean Sea Level (AMSL) reached during any flight
   DAX Function: MAX(dataset[altitudeAMSL])

6. Minimum Altitude Tuning: The lowest altitude tuning value recorded during all flights
   DAX Function: MIN(dataset[altitudeTuning])

7. Average Heading to Next Waypoint: The average direction the drone was heading towards the next waypoint
   DAX Function: AVERAGE(dataset[headingToNextWP])

Table : Local Position

1. Maximum Altitude: Determine the highest altitude reached using the MAX function
   DAX Function: Maximum Altitude = MAX('localPosition.z')

2. Average Velocity: Calculate the average velocity based on the localPosition.vx and localPosition.vy columns using the AVERAGE function:
   DAX Function: Average Velocity = AVERAGE('localPosition.vx')

3. Acceleration: You can calculate acceleration by finding the change in velocity over time using the DIVIDE function:
   DAX Function: Acceleration = DIVIDE(('Local Position'[localPosition.vz] - LAG('('Local Position', [localPosition.vz], 1), 'Timestamp' - LAG('('Local Position', 'Timestamp', 1))

4. Total Time Spent: Calculate the total duration of the data collection
   DAX Function: Total Time Spent = MAX('Timestamp') - MIN('Timestamp')

5. Minimum Velocity: Calculate the minimum velocity using the MIN function
   DAX Function: Minimum Velocity = MIN('localPosition.vx')

6. Maximum Velocity: Find the maximum velocity reached using the MAX function.
   DAX Function: Maximum Velocity = MAX('localPosition.vx')

Table : ESC Status

1. Total Operating Time: Calculate the total time the system is operational by finding the time duration between the first and last timestamps.
   DAX Function:Total Operating Time = MAX('Timestamp') - MIN('Timestamp')

2. Average RPM for Each Motor: Calculate the average RPM for each of the four motors using the AVERAGE function.
   DAX Function:
   Average RPM Motor 1 = AVERAGE('escStatus.rpm1')
   Average RPM Motor 2 = AVERAGE('escStatus.rpm2')
   Average RPM Motor 3 = AVERAGE('escStatus.rpm3')
   Average RPM Motor 4 = AVERAGE('escStatus.rpm4')

3. Voltage Drop: Calculate the voltage drop as the difference between the initial voltage and the final voltage for each motor.
   DAX Function:
   Voltage Drop Motor 1 = MAX('escStatus.voltage1') - MIN('escStatus.voltage1')
   Voltage Drop Motor 2 = MAX('escStatus.voltage2') - MIN('escStatus.voltage2')
   Voltage Drop Motor 3 = MAX('escStatus.voltage3') - MIN('escStatus.voltage3')
   Voltage Drop Motor 4 = MAX('escStatus.voltage4') - MIN('escStatus.voltage4')

4. Total Current Consumed: Determine the total current consumed by summing the current values for all four motors.
   DAX Function:
   Total Current Consumed = SUM('escStatus.current1') +
   SUM('escStatus.current2') + SUM('escStatus.current3') +
   SUM('escStatus.current4')

5. RPM Deviation from Setpoint: Measure the average deviation of RPM from a setpoint for each motor.

DAX Function:

RPM Deviation Motor 1 = AVERAGE([escStatus.rpm1] - [SetpointRPM1])

RPM Deviation Motor 2 = AVERAGE([escStatus.rpm2] - [SetpointRPM2])

RPM Deviation Motor 3 = AVERAGE([escStatus.rpm3] - [SetpointRPM3])

RPM Deviation Motor 4 = AVERAGE([escStatus.rpm4] - [SetpointRPM4])

4. Visuals/Graphs

Table : Control commands

1. Line Charts for Roll Rate, Pitch Rate, Yaw Rate:

Separate line charts for each rate variable can help to understand the rate of change in these angles over time.

2. Line Chart for Multivariate Time Series:

Plot multiple variables (e.g., Roll, Pitch, and Heading) on the same graph to see how they relate to each other over time. This can help to identify correlations or anomalies.

3. Histograms:

Create histograms for the numerical variables like Roll, Pitch, Heading, Roll Rate, Pitch Rate, Yaw Rate, Ground Speed, Climb Rate, and Throttle Percentage to understand their distribution and spot outliers.

4. Scatter Plots:

Scatter plots can help visualize relationships between variables. For example, we can explore the relationship between Roll and Pitch or between Ground Speed and Climb Rate.

5. Filter Controls and Slicers:

Use filter controls and slicers to allow users to interact with the data. For instance, users can select a specific time range or filter by other categorical variables.

Table : Sensor data

1. Line Chart for Flight Time vs. Distance:

Plot 'flightTime' against 'flightDistance' using a line chart. This can show the relationship between flight duration and the distance covered.

2. Scatter Plot for Altitude vs. Distance:

Create a scatter plot to see the relationship between altitude (either 'altitudeRelative' or 'altitudeAMSL') and 'flightDistance.' This can help identify patterns or correlations.

3. Line Chart for Altitude over Time:

Line chart to visualize how the 'altitudeRelative' or 'altitudeAMSL' changes over time. This can help in analyzing altitude trends during the flight.

4. Bar Chart for Distance to Home:

Bar chart to display 'distanceToHome' for different flights. This can help identify how far the drone is from home during the missions.

5. KPI Card for Key Metrics:

Use KPI cards to display summary statistics such as the average altitude, total flight time, or the maximum distance covered.

Table : Local Position

1. Line Charts for x, y, z coordinates vs. Timestamp:

This will give a time-series view of the position on each axis. We can create three separate line charts for x, y, and z.

2. Scatter Plots for localPosition.x vs. localPosition.y:

Scatter plots can help you understand the relationship between x and y coordinates.

3. Scatter Plots for localPosition.x vs. localPosition.z:

Scatter plots can help you understand the relationship between x and z coordinates.

4. Scatter Plots for localPosition.y vs. localPosition.z:

Scatter plots can help you understand the relationship between y and z coordinates.

5. Velocity Histograms for localPosition.vx, localPosition.vy, and localPosition.vz.:

This can help to understand the distribution of velocities.

Table : ESC Status

1. Time Series Line Chart for RPM1, RPM2, RPM3, RPM4:

Show how the RPM values change over time for each component.

2. Multi-line Chart for RPM, Current, and Voltage for Component:

Compare the behavior of RPM, current, and voltage for components over time.

3. Scatter Plot for RPM vs. Current:

Explore the relationship between RPM and current for all components.

4. Box-and-Whisker Plots for RPM, Current, and Voltage

Box-and-Whisker Plots visualize the distribution, outliers, and central tendency of the data.

5. Dashboard

Table : Control commands

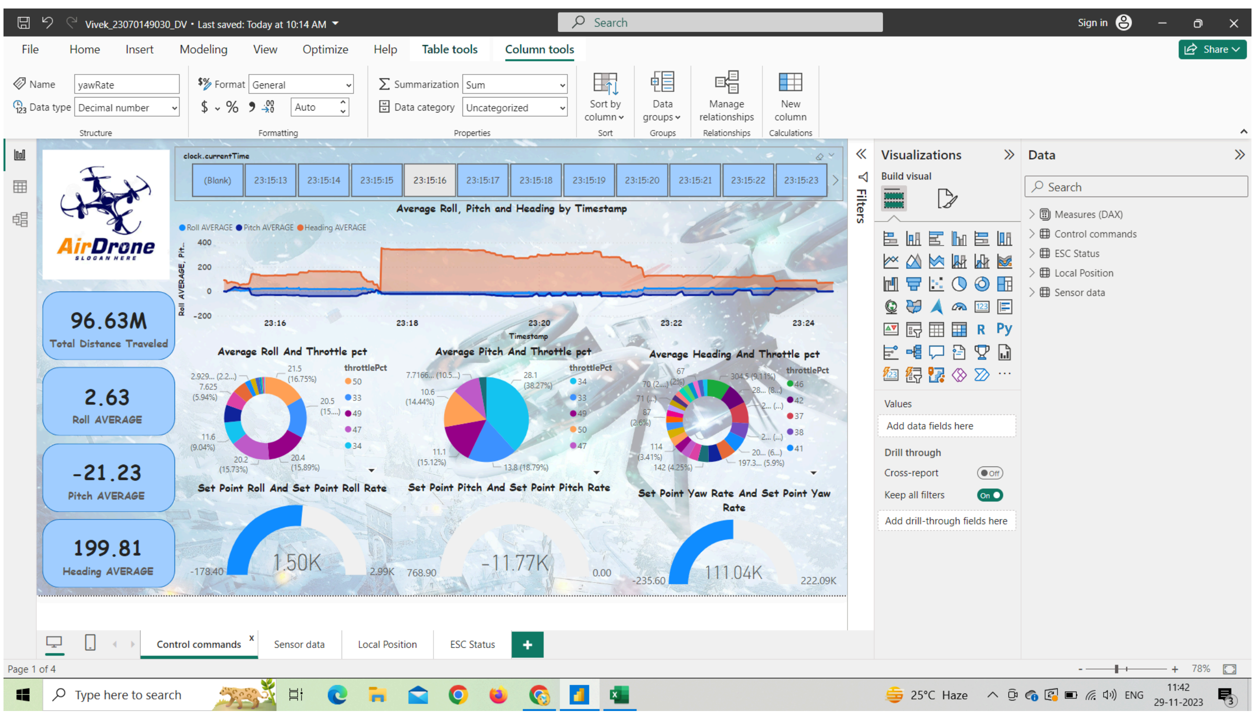


Table : Sensor data

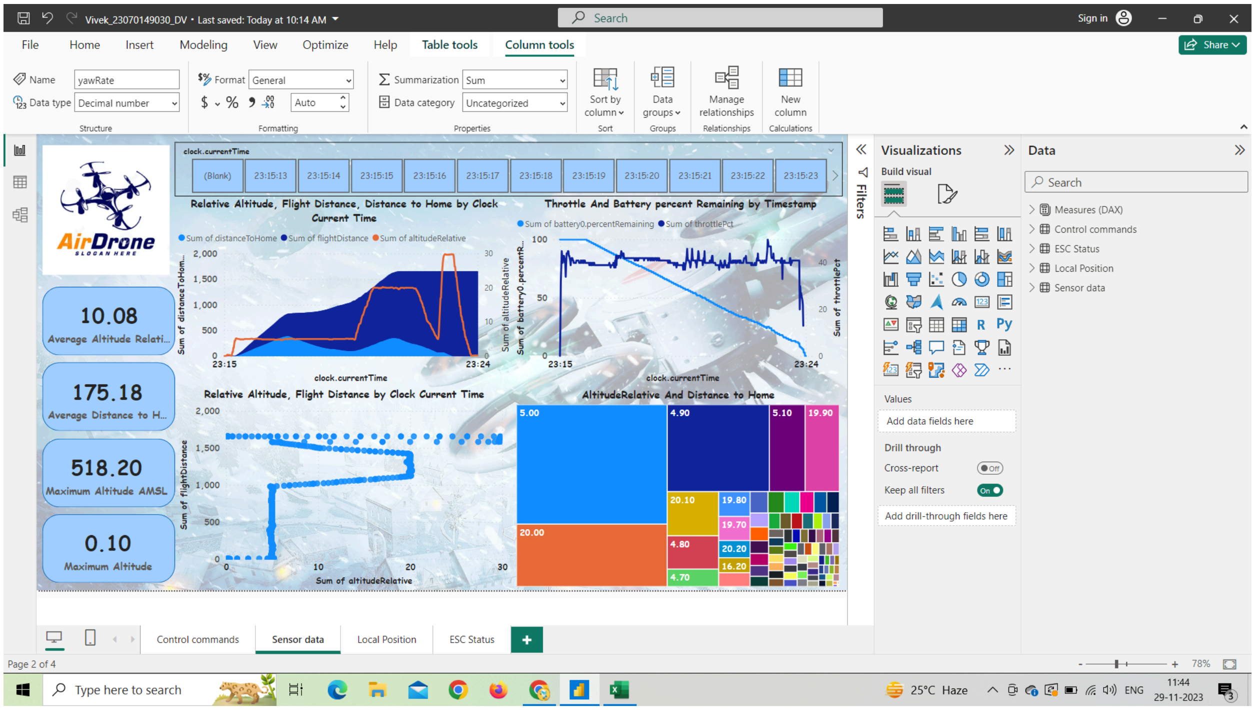


Table : Local Position

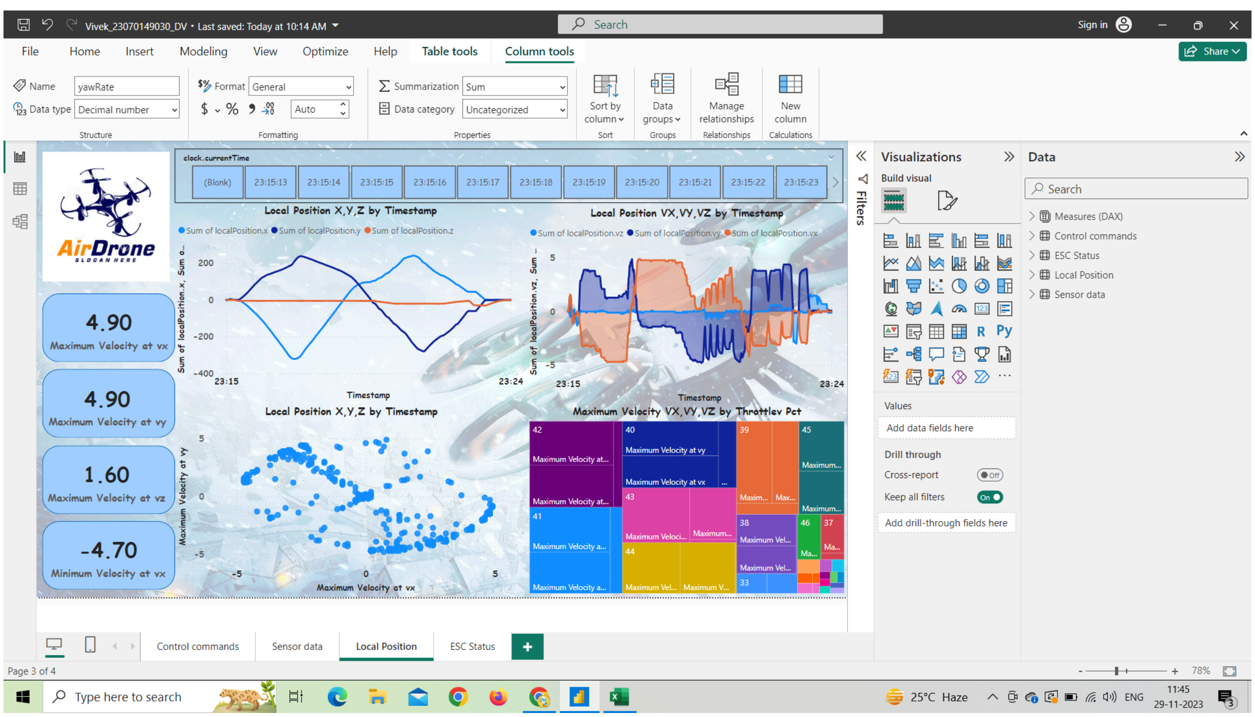
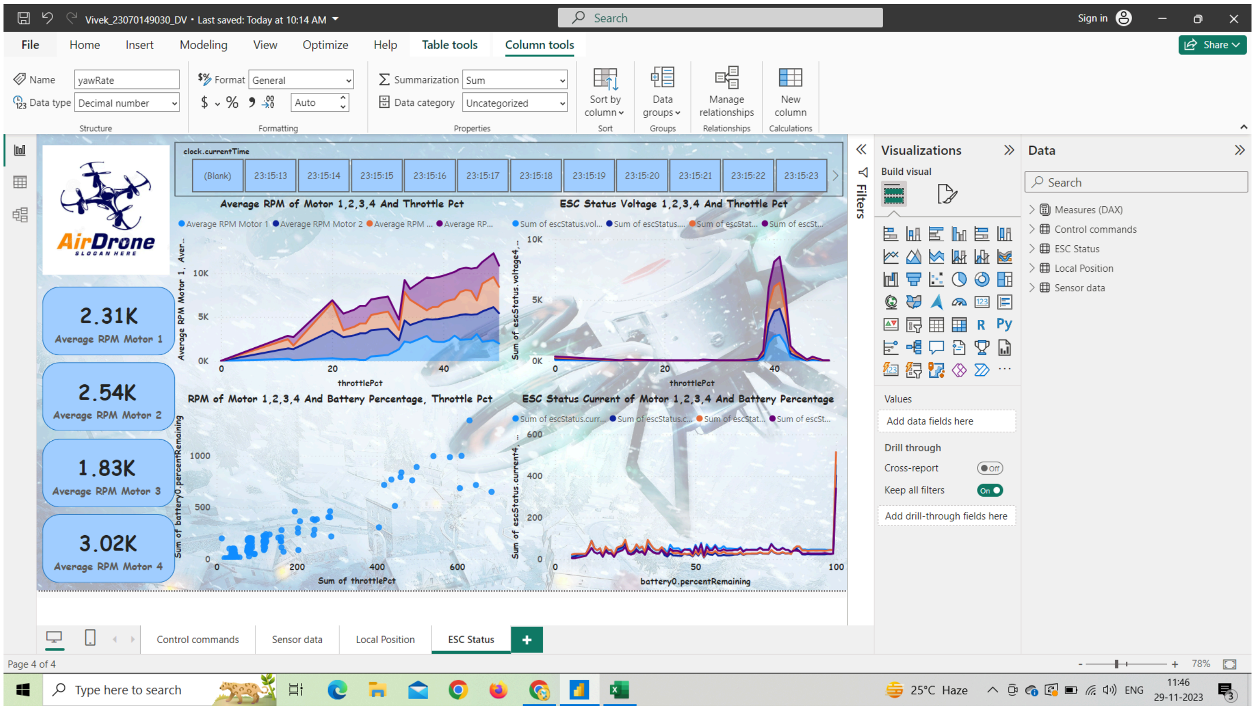


Table : ESC Status



References

[1]Whelan, J., Almehmadi, A. and El-Khatib, K., 2022. Artificial intelligence for intrusion detection systems in unmanned aerial vehicles. Computers and Electrical Engineering, 99, p.107784.

[2]Mohsan, S.A.H., Khan, M.A., Noor, F., Ullah, I. and Alsharif, M.H., 2022. Towards the unmanned aerial vehicles (UAVs): A comprehensive review. Drones, 6(6), p.147.

[3]Motlagh, N.H., Taleb, T. and Arouk, O., 2016. Low-altitude unmanned aerial vehicles-based internet of things services: Comprehensive survey and future perspectives. IEEE Internet of Things Journal, 3(6), pp.899-922.

[4]Balestrieri, E., Daponte, P., De Vito, L., Picariello, F. and Tudosa, I., 2021. Sensors and measurements for UAV safety: An overview. Sensors, 21(24), p.8253.