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Digital Forensic Analysis of Hybrid Scooter Motors using Smart Flow and Integrated Digital Forensics Standard

Yerly Ania Saputri[1], Ahmad Fazal[2], Aditya Wahyu Ningrat[3], Dedy Hariyadi[4,*]
[1,2,,3,4]Teknologi Informasi, Universitas Jenderal Achmad Yani Yogyakarta

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ABSTRACT

This study addresses the challenges of digital forensic investigations in connected hybrid scooter, particularly the Yamaha Fazzio scooter, where evidence integrity is often compromised due to limited acquisition methods and mobile device encryption. The objective of this research is to develop a standardized and efficient forensic framework tailored for hybrid scooters. The proposed method integrates guidelines from NIST SP 800-101 Rev.1 and ISO/IEC 27037:2012 into five standardized stages: data collection, evidence identification, acquisition, examination and analysis, and reporting. The acquisition stage was enhanced using the Smart Flow automation feature of Cellebrite UFED, which enables automated identification of Android devices and extraction of Y-Connect App data, including GPS logs and trip summaries. Experimental evaluation using a rooted Xiaomi Mi 5s Plus demonstrated successful acquisition of key digital evidence such as travel routes, distance traveled, average and maximum speeds, and fuel consumption. These findings support the development of standardized operating procedures (SOPs) for digital forensic investigations in the context of connected vehicle technologies.

Corresponding Author:

Dedy Hariyadi,
Teknologi Informasi,
Universitas Jenderal Achmad Yani Yogyakarta,
Jalan Siliwangi, Ring Road Barat, Banyuraden, Gamping, Sleman, Yogyakarta, Indonesia.
Email: *dedy@unjaya.ac.id

1. INTRODUCTION

Digital forensics is a scientific process used to collect, analyze, and report digital data to support investigations. This field utilizes various scientific methods to investigate crimes, legal violations, or inappropriate actions involving digital technology. Essentially, digital forensics aims to detect and solve crimes, while also providing the information needed by the legal system [1], [2].

As cybercrime increases, digital forensics is becoming increasingly important, particularly in uncovering criminal acts that exploit technology. One significant development in the world of transportation technology is the implementation of the concept of “connected vehicles,” which allows vehicles to function not only as a means of transportation, but also as a source of data that can be used for various purposes, including digital forensics [3].

In this context, vehicles such as hybrid scooters equipped with connectivity technology via smartphone apps are an interesting subject of research. One implementation of this technology is the Yamaha Fazzio hybrid scooter, which is equipped with the Y-Connect App. Through this app, various vehicle-related information, such as distance traveled, travel location, and operational time, can be accessed and synchronized in real-time, offering significant potential for collecting relevant data for digital forensic investigations [4].

Although the concept of "connected vehicles" has great potential in digital forensics, research on methodologies and best practices in collecting and analyzing data from connected vehicles is still limited. Therefore, this study aims to examine the digital forensic analysis methods applied to hybrid scooters by utilizing travel data obtained through the Y-Connect App. The Yamaha Fazzio was selected as the research subject due to its connectivity features, which are relevant to the needs of this study [5], [6].

This study used Linux-based devices, which are widely recognized as reliable platforms for efficient and measurable digital data processing. Linux was chosen as the operating system based on its advantages in maintaining data integrity, flexibility in information extraction, and ability to support various relevant digital forensic tools. This approach, the research is expected to produce valid and accurate data, which is an important prerequisite in forensic analysis of the concept of "connected vehicles" technology [7], [8].

With this foundation, this study aims to contribute to the development of knowledge in the field of digital forensics, particularly in relation to the application of "connected vehicle" technology concepts. The results obtained are expected to serve as a reference in the formulation of standard operating procedures for the collection and analysis of vehicle data in the context of investigations. Additionally, this research opens opportunities for the development of more adaptive security systems and the refinement of data protection protocols to safeguard user privacy and reduce the risk of sensitive information leaks that could be misused [9].

The present study focuses on identifying the most appropriate digital forensic analysis methods to apply to vehicles with high connectivity technology, such as the Yamaha Fazzio. In addition to developing analysis methodologies, this research also aims to provide practical contributions to the development of standard operating procedures (SOPs) for data collection and processing in the concept of "connected vehicle" technology. The findings of this research are expected to be beneficial for digital forensic practitioners in investigations, support technology developers in creating safer systems within the "connected vehicle" technology concept, and serve as a reference for researchers in the fields of data security and transportation systems based on the Internet of Things (IoT).

However, this research specifically focuses on the Yamaha Fazzio hybrid scooter due to the current limitations of connected vehicle models available in the Indonesian market. As of the time of this study, Yamaha is the only manufacturer providing consumer-grade connected vehicle technology (Y-Connect) that integrates directly with mobile applications. Therefore, this study deliberately concentrates on this model to ensure depth and consistency of analysis. Nonetheless, future research is recommended to extend the validation of this framework across other connected vehicle platforms and various Android smartphone brands (e.g., Samsung, Oppo, Vivo) as they become available, enabling broader generalization of digital forensic acquisition performance in connected vehicle ecosystems.

2. MATERIALS AND RESEARCH METHODS

The standardization of digital evidence handling in this study adopts research that has been conducted at Concordia University of Edmonton which integrates two standards, NIST SP 800-101 Rev.1: 2014 and ISO / IEC 27037: 2012. NIST SP 800-101 Rev.1:2014 has stages of digital forensics: Collection, Examination, Analysis, and Reporting [10]. While ISO/IEC 27037: 2012 has the stages of digital forensics: Identification, Collection, Acquisition, and Preservation [11]. So the integration of 1 standardization into 6 stages: Identification, Collection, Acquisition, Preservation, Examination & Analysis, and Reporting, see [12].

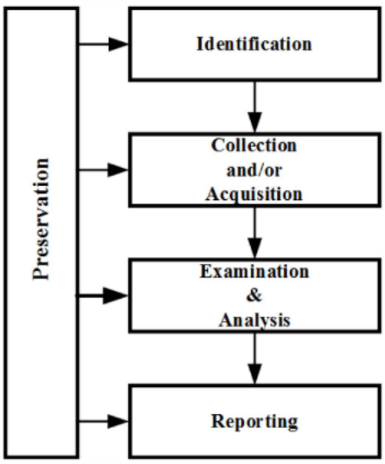
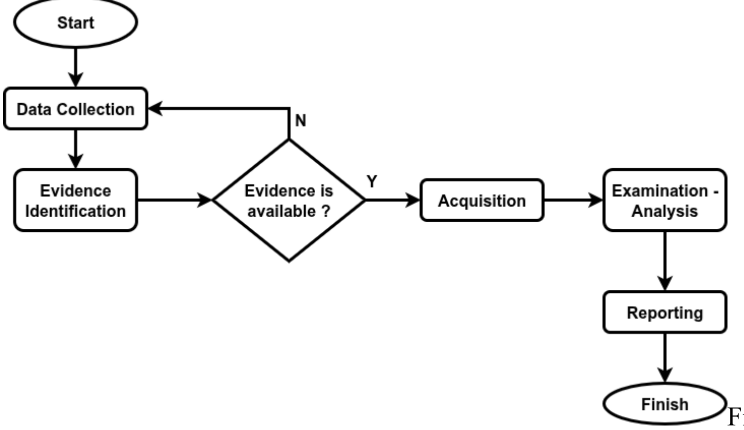


Figure 1. Integrated Digital Forensic Standards

This research adopts the 6 stages that are harmonized with forensics on hybrid scooter, Yamaha Fazio into 5 stages, namely Data Collection, Evidence Identification, Acquisition, Examination - Analysis, and



Reporting, see Figure 2.

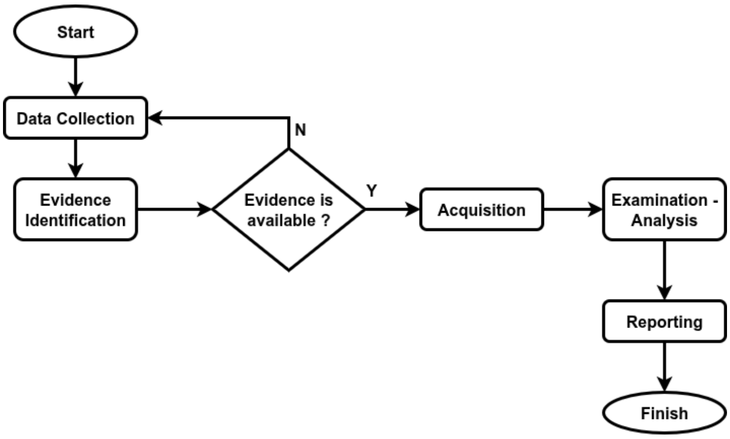


Figure 2. Stages of Research

2.1. Data Collection

In order to support the digital forensics process on motor vehicles, a series of scenarios are carried out to support data collection on driving activities. The scenarios were executed in a variety of travel modes, traversing diverse routes. Trips were made at various times, including rush hour and light traffic conditions, to ensure the completeness of the scenario data [13]. During the course of the trip, data from the vehicle—a Yamaha Fazio motorcycle—was automatically synchronized with the Y-Connect App on the researcher's mobile phone. The data collected encompassed various parameters such as location, time, speed, distance traveled, fuel consumption, and battery status.

2.2. Evidence Identification

The evidence utilized in the research is a smartphone, specifically the Xiaomi Mi 5s Plus, which has been rooted and previously connected to the Yamaha Fazzio hybrid scooter through the Y-Connect App. The Communication Control Unit (CCU) facilitates connectivity between the motorcycle and the Y-Connect (Yamaha Motorcycle Connect) application through bluetooth connection. The CCU facilitates direct access to critical motorcycle data via a mobile device, thereby enhancing operational efficiency and safety. The Y-Connect App offers a range of features, including information regarding motorcycle condition, trip history, the most recent parking location, and maintenance notifications. Table 1 illustrates the identification of evidence utilized in this study.

Table 1. Identification of Evidence

No	Evidence	Description
1	Xiaomi Mi 5s Plus	Mobile phone with MIUI OS compatible with Android 8.0.0
2	Y-Connect	Mobile Apps created by Yamaha to connect CCU on Yamaha Fazio motorcycle via Bluetooth

2.3. Acquisition

Smart Flow is an automation system within the Cellebrite Universal Forensic Extraction Device (Cellebrite UFED) software designed to simplify the process of acquiring and extracting forensic data from Android devices. The system functions by automatically identifying the device type and assigning the most suitable acquisition and extraction method based on the device architecture and its security configuration,

thereby eliminating the need for manual selection by the digital examiner. This approach is designed to enhance efficiency, minimize operational error rates, and expedite response times in digital investigations.
This system enables the automatic activation of live acquisition and extraction methods upon device connection, thereby eliminating the need for manual identification of the device profile during the extraction process. Cellebrite UFED boasts the capacity to manage a range of data capture scenarios, encompassing devices with encrypted or deleted data, while ensuring the integrity of digital evidence within a legal framework [14].

3. RESULTS AND ANALYSIS

3.1. Evidence Extraction

Digital evidence extraction in the digital forensics process involves the methodical creation of bit-by-bit copies of digital devices. This process ensures the acquisition of complete and integrity-preserved data, which is then subjected to rigorous analysis. In certain cases, the condition of electronic evidence, such as smartphones, may experience operational issues (e.g., screen not working or screen locked) during the collection process, hindering the acquisition of digital evidence. However, the utilization of the Smart Flow method enabled the successful identification and acquisition of the phones. Table 2 offers a concise overview of the electronic evidence that has been successfully identified through the utilization of this method.

Table 2. Collection Summary Report

No	Type/Model	Description
1	Extraction Type	File System
2	Extraction Metho	Apps
3	Device Model	Mi 5s Plus
4	OS Version	Android 8.0.0
5	Chipset	msm8996
6	Security Patch Level	2018-10-01
7	Vendor	Xiaomi
8	Device Rooted	Yes
9	Live Encryption State	Full_Disk

The closed and automated nature of Smart Flow is also recognized in recent studies. Hargreaves et al. emphasized that many commercial forensic tools operate as black-box systems, offering automation without exposing intermediate operational metrics [15]. Similarly, the Cellebrite UFED 4PC Overview Guide v7.66 and Cellebrite Smart Flow documentation [16] describe Smart Flow as a single-step automated process that accelerates evidence extraction but does not reveal internal timing or object-level success rates. Furthermore, NIST SP 800-101 Rev.1 highlighted that automation in digital forensic tools, while improving efficiency, may reduce transparency and external verifiability. These findings substantiate the methodological limitation addressed in this research, where Smart Flow's automation prevents direct measurement of performance indicators but ensures standardized, repeatable, and forensically sound acquisition results.

The acquisition process using the Smart Flow system generated a digital evidence file named Xiaomi_MI5sPlus.zip, containing data from the /data/data/ directory. Prior to extraction, the file's integrity was verified using the SHA-1 hashing algorithm, which produced the hash value c2c2b0282014ce0eaf4c9a85889dc1b41021b8ad. This verification procedure follows international digital forensic standards that recommend cryptographic hashing to record and preserve the integrity of digital evidence [17], [18].

The Smart Flow method is a systematic approach designed to assist Digital Evidence First Responders (DEFRs) in the acquisition of digital evidence. The DEFR system utilizes automatic detection capabilities to identify pertinent digital evidence, such as the Y-Connect App, within the `jp.co.yamahamotor.yamahamotorcycleconnect.sccu` folder, employing live extraction techniques to facilitate this identification, see

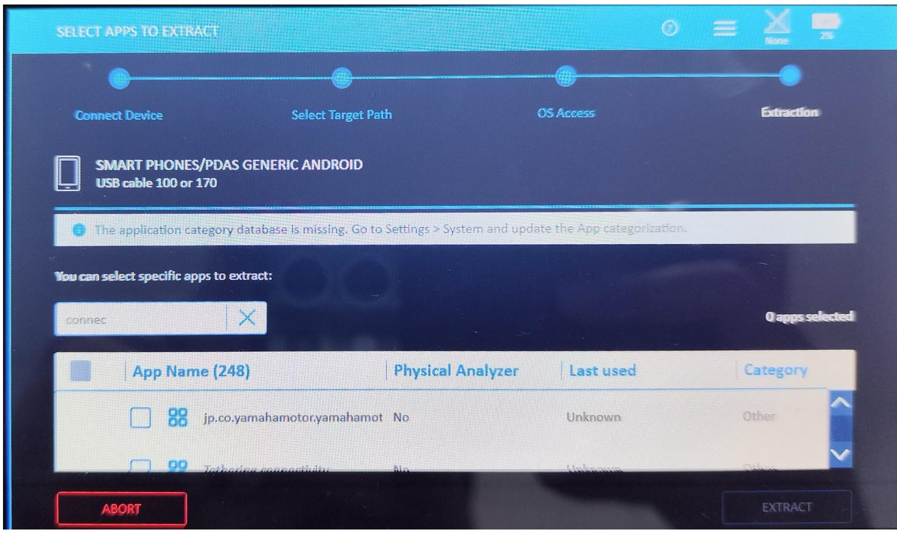


Figure 3. However, the utilization of the Smart Flow method enabled the successful identification and acquisition of the phones. Table 2 offers a concise overview of the electronic evidence that has been successfully identified through the utilization of this method.

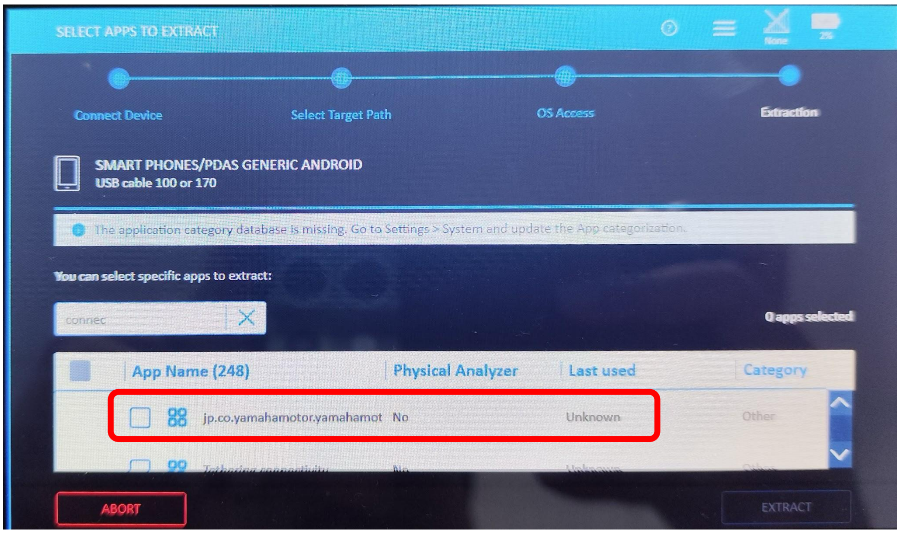


Figure 3. Live Extraction

3.2. Examination and Analysis

A smartphone with the MIUI operating system, which is based on Android 8.0.0, and the Y-Connect App displays a dashboard that summarizes trip data synchronized with the CCU on the Yamaha Fazzio motorcycle. Information that includes synchronization results as shown in

Figure 4 with detailed information including:

1. **Trip Time,** all trips made are recorded in detail with accurate timestamps [19]. This allows users to track the duration of the trip as well as when the trip was made. This feature is especially useful for users who want to manage their travel time effectively [20].
2. **Trip Location,** the app records the vehicle's location based on GPS, allowing visual mapping of the route [21]. With this feature, users can find out the route they have taken in full and in detail, including the starting and ending points of the trip. This data is also useful for route analysis needs or ensuring travel safety [22].
3. **Vehicle Data Information**, mileage, average speed, and fuel consumption are available in detail. This data provides important insights into vehicle performance, allowing users to identify fuel usage patterns and trip effectiveness. In addition, this data can also assist in the maintenance of the vehicle to keep it in optimal condition [23].

Figure 4. Riding Dashboard

The examination and analysis process involves the careful scrutiny of a digital evidence copy, encompassing the extraction and subsequent analysis of pertinent data to facilitate comprehension and discernment. In the context of Android smartphone devices, the digital evidence that can be found includes .sqlite database files [24]. The .sqlite file located in the `/data/data/jp.co.yamahamotor.yamahamotorcycleconnect.sccu/databases` folder is designated as `y_connect.db`. The examination of this file or digital evidence is conducted using DB Browser for SQLite software. The digital evidence in question comprises numerous tables that contain clues pertaining to the utilization of Yamaha Fazio hybrid motor scooters. A notable example is the `riding_log` table, which is particularly relevant in this context. The `riding_log` table is extracted through the DB Browser for SQLite software into a `riding_log.csv` file, which is then analyzed using spreadsheet software.

Table 3 presents a comprehensive overview of the `riding_log` table's structural design. Within this article, several columns are highlighted as potential sources of digital evidence. The potential evidence encompasses the duration required to initiate engine ignition, the time to deactivate the engine, the trajectory of the journey, the distance traversed, the maximum velocity attained, and the fuel consumption.

Table 3. Riding log table structure

No	Field Name	No	Field Name	No	Field Name
1	**dc_key**	16	total_mileage	31	merge
2	title	17	**mileage**	32	unmatch_flag
3	**start_position**	18	fuel_efficiency	33	delete_flag
4	**end_position**	19	**max_speed**	34	enable_rl_flag
5	dc_start_ts	20	**fuel_used**	35	display_flag
6	dc_end_ts	21	average_eg	36	dcdd_processing_status
7	dc_time	22	eco_point	37	dcdh_update_status
8	**thumbnail_path**	23	average_throttled	38	create_time
9	**riding_log_path**	24	start_odo	39	update_time
10	total_photo_number	25	end_odo		
11	weather_service_id	26	max_atmospheric		
12	weather_id	27	min_atmospheric		
13	weather_icon_code	28	rate		
14	temperature	29	comment		
15	**average_speed**	30	tag		

Table 4 shows the summary results of the journey analysis on digital evidence using the SQL command below to find out the entire journey.

```
SELECT
  dc_key,
  title AS "Rute",
  mileage AS "Mileage (km)",
  strftime('%H:%M:%S', dc_time / 1000, 'unixepoch') AS "Time",
  ROUND(average_speed, 2) AS "Average Speed (km/jam)",
  ROUND(max_speed, 2) AS "Max Speed (km/jam)",
  ROUND(fuel_used, 3) AS "Fuel Used (L)",
  thumbnail_path AS "Evidence - Thumbnail",
  riding_log_path AS "Evidence - Log GPS"
FROM
  riding_log
WHERE
  dc_time > 0;
```

Table 4. Trip Logs

dc_key	Rute	Total Mileage (km)	Time	AVG Speed (km/jam)	Max Speed (km/jam)	Fuel Used (L)
2024101991CE5		0	00:00:30	0	0	0
2024101991F41	Special Region of Yogyakarta Sleman Regency → Special Region of Yogyakarta Sleman Regency	0	00:12:13	0	0	0
2024102059C97		0	00:01:05	0	0	0
2024102062A53	Special Region of Yogyakarta Yogyakarta → Special Region of Yogyakarta Sleman Regency	14.4	00:28:20	30	62	0.245
202410206800D	Special Region of Yogyakarta Sleman Regency → Central Java Klaten	17	00:29:27	34	69	0.266
202410207E002	Central Java Klaten → Central Java Klaten	3.8	00:08:48	25	43	0.067
202410207F55C	Central Java Klaten → Special Region of Yogyakarta Bantul Regency	31	01:06:22	28	55	0.482
202410208AF87	Special Region of Yogyakarta Bantul Regency → Special Region of Yogyakarta Sleman Regency	2.4	00:06:22	22	67	0.042

The query also shows the location of digital evidence in the form of GPS log files stored using json file format and screenshots of travel route resumes as in

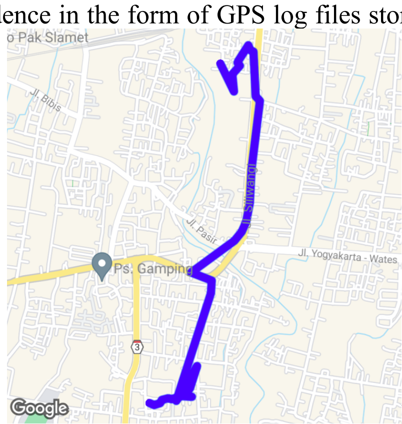


Figure 5. The

digital evidence snippets in the form of GPS logs are as below. While Table 5 shows a summary of the location of potential digital evidence.

{"ContentsGPS":"110.3288826,-7.7919539","ContentsSpeed":"1","timestamp":"2024-10-20T15:54:57.930+07:00"}],"DC-KEY":"202410208AF87","DEVICE-TYPE-ID":"0000","GIGYA-UUID":"32ab46fced1c47c88a2c42eb80fcc91d","locationPermission":"1","locationSetting":"1","OS-Info":"Android 8.0.0","timestamp":"2024-10-20T15:56:17.150+07:00"}

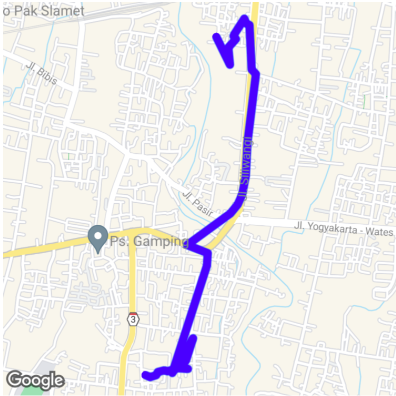


Figure 5. Screenshot of Trip Resume

Table 5. Location of Potential Digital Evidence

dc_key	Evidence - Thumbnail	Evidence - Log GPS
2024101991CE5	-	-
2024101991F41	-	-
2024102059C97	-	-
2024102062A53	/data/user/0/jp.co.yamahamotor.yamahamotorcycleconnect.sccu/files/Image/2024102062A53/Capture/image.png	/data/user/0/jp.co.yamahamotor.yamahamotorcycleconnect.sccu/files/gpsd1dc/00000002119507_GPSD1DC_TEMP_2024102062A53.json
202410206800D	/data/user/0/jp.co.yamahamotor.yamahamotorcycleconnect.sccu/files/Image/202410206800D/Capture/image.png	/data/user/0/jp.co.yamahamotor.yamahamotorcycleconnect.sccu/files/gpsd1dc/00000002119507_GPSD1DC_TEMP_202410206800D.json
202410207E002	/data/user/0/jp.co.yamahamotor.yamahamotorcycleconnect.sccu/files/Image/202410207E002/Capture/image.png	/data/user/0/jp.co.yamahamotor.yamahamotorcycleconnect.sccu/files/gpsd1dc/00000002119507_GPSD1DC_TEMP_202410207E002.json
202410207F55C	/data/user/0/jp.co.yamahamotor.yamahamotorcycleconnect.sccu/files/Image/202410207F55C/Capture/image.png	/data/user/0/jp.co.yamahamotor.yamahamotorcycleconnect.sccu/files/gpsd1dc/00000002119507_GPSD1DC_TEMP_202410207F55C.json
202410208AF87	/data/user/0/jp.co.yamahamotor.yamahamotorcycleconnect.sccu/files/Image/202410208AF87/Capture/image.png	/data/user/0/jp.co.yamahamotor.yamahamotorcycleconnect.sccu/files/gpsd1dc/00000002119507_GPSD1DC_TEMP_202410208AF87.json

4. CONCLUSION

This study successfully designed and implemented a standardized digital forensic framework for connected hybrid scooter, using the Yamaha Fazzio scooter as a case study. The framework integrates two internationally recognized standards, NIST SP 800-101 Rev.1 and ISO/IEC 27037:2012, into five main stages: data collection, evidence identification, acquisition, examination and analysis, and reporting. The acquisition process was conducted using the automated Smart Flow feature within Cellebrite UFED on a rooted Xiaomi Mi 5s Plus device, resulting in the successful extraction of comprehensive digital data from the Y-Connect App, including the `y_connect.db` database file, GPS logs in JSON format, and image-based trip summaries.

The extracted data revealed that the riding_log table contains relevant digital forensic parameters such as trip duration (`dc_time`), mileage (`mileage`), average and maximum speed (`average_speed`, `max_speed`), and fuel consumption (`fuel_used`). These data were analyzed using DB Browser for SQLite and exported to CSV format for further evaluation. The findings demonstrate that the applied acquisition and analysis methods can retrieve and managing digital evidence in a systematic, valid, and forensically sound manner.

This research opens opportunities for further measurable development, including replication of the acquisition method across various Android device models to evaluate consistency and extraction performance. Quantitative evaluation of data readability, attribute completeness, and the integrity of GPS log files can serve as performance indicators. By adopting a standardized and data-driven approach, the results of this study contribute to the formulation of adaptive Standard Operating Procedures (SOPs) for digital forensics in connected vehicle technologies and support the advancement of data security frameworks in the context of the Internet of Things (IoT).

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