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Live Location Sharing System (L2S2): Empowering Management of Unmanned Aircraft Systems (UAS) Operations

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Transparency and confidence-building measures in Unmanned Aircraft Systems (UAS) operations continue to be important topics of discussion in various contexts. Transparency helps build trust and alleviate concerns about the use of UAS, especially in sensitive areas or situations where privacy and security are paramount. Meanwhile, confidence-building measures aim to establish trust and mitigate potential risks associated with UAS operations, particularly in complex UAS operations involving multiple teams. These measures include implementing systems that enable the identification and tracking of UAS operations activities that can be achieved through technologies such as global positioning system (GPS)-based tracking systems. Although there are several UAS operations GPS-based management systems available in the market, it requires a certain initial investment cost that creates a barrier for some parties, particularly smaller organisations or those with limited budgets. Therefore, in this study, we have developed a web-based application called as Live Location Sharing System (L2S2) by leveraging the capabilities of Traccar, a free and open-source GPS tracking system. Through this system, the movement activities of the Malaysian Space Agency (MYSA) UAS operation teams can be monitored in real-time by the mission commander, which has finally empowered the management of UAS operations as a whole.

Keywords: Web-based GPS Tracking System; Drone Operation Management; Online Monitoring System.

I. INTRODUCTION

Management of Unmanned Aircraft Systems (UAS) operations involves overseeing various aspects to ensure safety and efficient operation. Among the main considerations are regulatory compliance, standard operating procedures, risk assessment and mitigation, qualified personnel, equipment maintenance and inspections, mission planning and execution, communication and coordination, and data management. While there have been significant advancements in the management of UAS operations, weaknesses still exist in the current landscape, which is the difficulty in real-time monitoring of the UAS operation team's activities, particularly in complex UAS operations involving multiple teams. During the operations period, each team have specific tasks and responsibilities, and coordinating their movements and actions in real-time is too complex. Without real-time tracking, mission commander may lack accurate information on the location and activities of UAS operation teams, leading to reduced oversight and coordination and high potential to create risk to safety, inefficient resource allocation and potential conflicts among the teams.

Therefore, to address these weaknesses, advancements in the management of UAS operations, including tracking technologies, communication infrastructure, and data management systems are needed. Implementing robust real-time tracking systems, establishing reliable communication networks, and developing user-friendly data visualisation tools can improve monitoring capabilities. Although there are several UAS operation monitoring systems available in the

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market, it requires a certain initial investment cost that can be a barrier for some parties, particularly smaller organisations or those with limited budgets. Additionally, the existing systems available on the market have limited capabilities and are tailored for specific use cases, making them less adaptable to diverse operational needs. These factors contribute to the challenges in effectively monitoring UAS operations.

To address these challenges, we have developed a web-based system called the Live Location Sharing System (L2S2) by leveraging the capabilities of Traccar (Traccar, n.d.), a free and open-source GPS tracking system in order to manage the movement of the Malaysian Space Agency (MYSA) UAS operation teams. Traccar's capability as a GPS tracking system has been proven in the study of a low-cost GPS tracking system to monitor small-scale fisheries (vessels under 12 meters) and ambulance position tracking to control traffic light systems (Seniman *et al.*, 2020; Tassetti *et al.*, 2022). As such, the contributions of this study can be summarised as follows:

- Describes a comprehensive L2S2 development architecture and methodology.
- Details of L2S2 proof of concept (POC) activities and results.
- Performance analysis of L2S2 against existing UAS operation monitoring systems by Da-Jiang Innovations (DJI), Unifly and d-flight Società per azioni (S.p.A) but considering an extension of scenarios and other improvements in methodology, as shown in Table 1.

The rest of the paper is organised as follows: Section II discusses the type of GPS-based tracking system specifications and capabilities. Section III presents the methodology of the study. The results of the study are discussed in Section IV. Finally, Section V concludes the article and the way forward.

II. GPS-BASED TRACKING SYSTEM FOR MANAGEMENT OF UAS OPERATIONS

GPS-based tracking systems are indeed recognised as a valuable approach for monitoring the movement of unmanned aircraft systems (UAS) operation teams on a global scale. By incorporating GPS technology into the UAS team's equipment, it becomes possible to track their movements and monitor their operations in real-time. There are various types of GPS tracking systems available for operation and fleet management purposes, and these include:

i. Active GPS Tracking Systems: Active GPS tracking systems provide real-time location updates at regular intervals. They are often used for real-time monitoring of fleet vehicles, allowing mission commander to track their movements, optimise routes, and respond to any emergencies or deviations (Bertagna, 2010; PowUnity, 2021).
ii. Passive GPS Tracking Systems: Passive GPS tracking systems store location data in the device, which can be downloaded and analysed later. These systems are useful for reviewing historical data, analysing teams' movement behaviour, and investigating incidents after they occur (Bertagna, 2010; PowUnity, 2021).
iii. Hybrid GPS Tracking Systems: Hybrid systems combine both cellular and satellite technologies to provide reliable and continuous tracking. They switch between the two modes based on the availability of network coverage, ensuring uninterrupted monitoring in diverse environment (Bertagna, 2010).

In the meantime, there are different types of platforms available to display the GPS tracking information. The platform GPS tracking system refers to the software or online interface that allows mission commander to monitor and manage the tracked teams or personnel. It provides a centralised dashboard where mission commander can view real-time location data, generate reports, set up alerts, and perform other administrative functions. Among the common types of platforms used in GPS tracking systems are:

i. Web-Based Platforms: Web-based platforms are accessed through a web browser on a computer or mobile device. These platforms offer flexibility and convenience, as they can be accessed from anywhere with an internet connection. They usually provide interactive maps, real-time tracking, historical data analysis, and various management tools.

ii. Mobile Applications: Many GPS tracking systems offer mobile applications that can be installed on smartphones or tablets. These apps provide similar functionality to web-based platforms but offer the convenience of on-the-go access.

For the development of the L2S2 application system, we have used satellite-based GPS tracking techniques along with a web-based operating platform. In general, satellite-based GPS systems are indeed free for public use. Among the most prominent global satellite-based GPS systems are the Global Positioning System (GPS), which is owned and operated by the United States government, Global Navigation Satellite System (GLONASS), owned and operated by Russia's counterpart, Galileo, which was developed by the European Union (EU) and the European Space Agency (ESA) and BeiDou, China's satellite navigation system. These satellites transmit signals that can be received by GPS receivers, including those in smartphones. Smartphones nowadays are equipped with GPS receivers that can accurately receive signals from multiple satellites, allowing them to determine the device's location with high precision.

According to a European Union Agency for the Space Programme Earth Observation (EUSPA EO) and GNS Market Report, the Global Navigation Satellite Systems (GNSS) market is set to grow steadily across the next decade from 1.8 billion units in 2021 to 2.5 billion units in 2031 (EUSPA, 2022). This has paved the way for the popularity of navigation services like Waze and Google Maps, which utilise GPS technology to provide real-time navigation, traffic updates, and other location-based services. The availability of accurate GPS signals and the advancement of smartphone technology have greatly contributed to these navigation services' widespread use and effectiveness.

Table 1. System Capabilities Comparison.

Features	**Web-Based UAS Operations Management System**			
	L2S2	**DJI Flight Hub 2 (Free Public Beta)**	**Unifly Unmanned Traffic Management**	**D-Flight**
Number of Free Supported Devices	Unlimited	Unlimited (Only for Selected DJI Enterprise Products)	Unlimited	Unlimited
Client Apps/ Devices (Transmitter)	Traccar Client	Selected DJI Enterprise Products	BLIP (Drone above 1kg MTOW)	-
Type of Server (Receiver)	User Server	Developer Server	Developer Server	Developer Server
Able to Receive Real-time Drone Location	No	Yes (DJI Products)	Yes	No
Able to Receive Real-time Pilot Location	Yes	Yes (DJI Products)	Yes	Yes
Auto Follow Feature	Yes	Yes	Yes	No
Storing Information of Device Location	Yes	Yes	Yes	Yes
Displaying the Coordinates on the Dashboard	Yes	Yes	Yes	Yes
Displays the Transmitter Battery Status	Yes	Yes	Yes	Yes
Displaying Transmitter Status	Yes	Yes	Yes	Yes
Dashboard Modification	Yes	No	No	No
Geofence	Yes	Yes	Yes	Yes
Import Geofence	Yes (GXP format)	Yes (KML Annotation)	No	Yes

In the meantime, web-based service applications have gained significant attention and popularity compared to traditional desktop applications in recent years. This trend is attributed to several factors, namely accessibility, cross-platform compatibility, ease of updates and maintenance, collaboration and sharing, scalability, and cloud integration (Ahmad Fauzi *et al*., 2023). On top of that, web-based applications also offer several advantages over mobile applications, such as cost-effectiveness, instant updates, and easier deployment. In the current landscape, the advancement of communication satellite technology, especially in low Earth orbit (LEO), as exemplified by SpaceX's Starlink satellite internet constellation, offers reliable internet access to areas where traditional terrestrial infrastructure is limited or non-existent. It is also aligned with the potential future trend of 6G mobile technology, where user devices will be able to connect directly to the internet network through satellite services (Giordani & Zorzi, 2021).

In the current market, there are several web-based service applications of satellite-based GPS tracking systems available for the management of UAS operations. Therefore, in Table 1, we have summarised and compared the capabilities of those systems with the capabilities of the L2S2 (Unifly, 2020; D-Flight, 2021; DJI, 2023).

III. L2S2: SYSTEM ARCHITECTURE AND DEVELOPMENT METHODOLOGY

Although all the drone systems available on the market are equipped with a GPS receiver, the proprietary technology prevents the information from being extracted for other purposes. At the same time, installing or attaching an external GPS receiver device to a drone without proper airworthiness testing and approval is considered an offence under the regulations enforced by aviation authorities. Therefore, to encounter this barrier, L2S2 was designed and developed to track the real-time location of the drone pilot through his smartphone. Overall, the development methodology of L2S2 is summarised and illustrated in the diagram as shown in Figure 1 and an explanation of each component is briefly described in the following subsections.

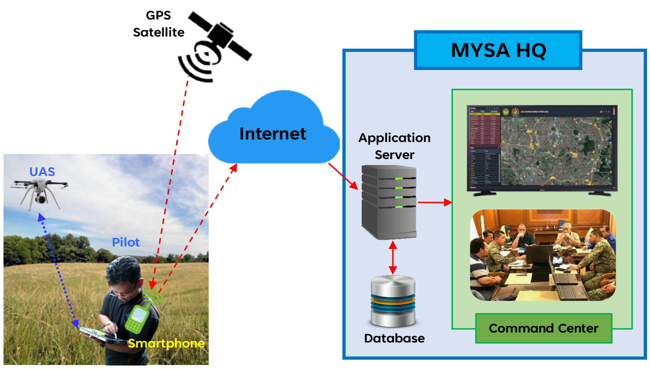

Figure 1. Overview of L2S2 Development Methodology.

A. Smartphone

Traccar Client is used to send GPS information to L2S2 by installing this mobile app on an iOS or Android smartphone. The smartphone sends the data using the OSM Automated Navigation Directions (OSMAND) protocol through a long-term evolution (LTE) or 3G network. Therefore, to ensure the smartphone sends the data to L2S2 all the time, phones need to be connected to a 3G or LTE internet connection, and 'Location permission' for the Traccar Client must be set to 'Allow all the time'. In addition, to get real-time GPS tracking, the smartphone battery must not be set in 'Power Saving Mode' and the phone must 'Allow background activity'. In the Traccar Client, a unique identifier (ID) as device identifier and L2S2 server IP address are set.

B. Application Server and Database

L2S2 is modified from the legacy version of Traccar. Similar to Traccar, this system is developed based on the Netty framework pipeline and the Jetty web server. The third-party services are used in L2S2 for geocode, reverse geocode, and geolocation features. Meanwhile, the web app is being developed using JavaScript, Cascading Style Sheets (CSS), and HyperText Markup Language (HTML). L2S2 is installed on a 64-bit Windows 11 computer that works as a server and uses an H2 embedded database. In L2S2, some modifications have been made, such as:

i. Web app graphical user interface (GUI) icons, colour, and background.
ii. Google Maps added in basemap option.
iii. The database field size has increased from 4096 to 65535. Therefore, the generated geofences from the

geographic information systems (GIS) software can be imported into L2S2.

iv. Reverse geocode for search location on the basemap is added as one of the features in L2S2.

v. The geocode feature is configured in L2S2.

vi. The Extensible Markup Language (XML) configuration file is configured to solve the jumping GPS location.

L2S2 can be accessed via any kind of web browser, including Internet Explorer. L2S2 receives data that is sent by the tracked or detected devices through Traccar Client, such as GPS data (latitude, longitude, and altitude), device battery information, GPS accuracy, device speed, and timestamps. The architecture of L2S2 is shown in Figure 2, and all available features in L2S2 are listed in Table 2.

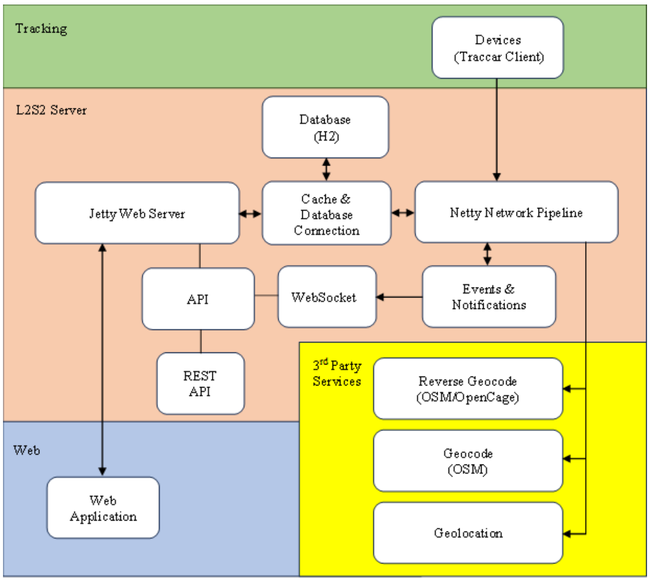

Figure 2. L2S2 Architecture.

Table 2. Available Features in L2S2.

Features	Information
Numbers of Supported Devices	Unlimited
Multiple Basemap Option	Yes (Google Maps, Open Street Map, Bing Map, Baidu Map, Yandex Map, and Carto Basemap)
Support All Types of Web Browser	Yes
Geofences	Yes
Import Geofences	Yes
Auto Follow Feature	Yes
Live Routes	Yes
Reverse Geocode	Yes
Geocode	Yes
Recording Device Location Information	Yes
Displaying the Device Coordinates	Yes
Displays the Device Altitude	Yes
Displays the Battery Status of the Monitored Device	Yes
Displays the Online Status of the Monitored Device	Yes
Changing the Device Position Icon	Yes

IV. L2S2: PROOF OF CONCEPT ACTIVITIES AND RESULTS

Overall, the implementation of proof of concept (POC) activities is carried out based on the flow chart as shown in Figure 3. Explanation for the roles of each box in the flowchart is detailed in the next subsection (4.1 to 4.4.).

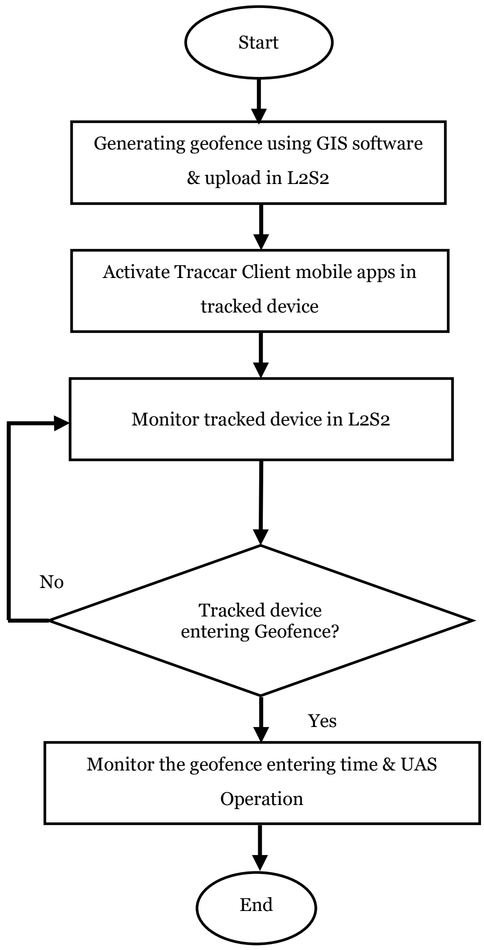

Figure 3. Workflow for Monitoring Drone Team Operation.

A. Geofence

After receiving operation commands from the management, all geofences for the UAS operation need to be generated using GIS software and imported into L2S2. The geofences were generated based on the UAS frequency range and elevation data surrounding the UAS operating area. The generated geofences are used as a reference for UAS areas of operation where the drone needs to be operated only within this zone. Therefore, each time the UAS team passes through the generated geofences, L2S2 will trigger and send notifications.

B. Activating the Traccar Client

When the UAS team starts moving to the operational area, the Traccar Client on the UAS team personnel's smartphone will be activated. Thus, every movement and location of the MYSA UAS team can be identified and monitored in real-time.

C. Monitoring Tracked Devices in L2S2

In L2S2, it will show the current location and movement of the team on the basemap. The mission commander will therefore be aware of the team members' current travel status to the UAS operational area based on the information shown in L2S2. L2S2 also has the capability to show the live route of tracked or detected devices and follow the moving devices by using the 'Live Routes' and 'Follow' features (Figure 4). The accuracy of the GPS position depends on the used device; therefore, for mobile phones, GPS accuracy is usually about 5 meters in the open sky (Diggelen & Enge, 2015; Diggelen, Want & Wang, 2018).

Thus, if the device stagnates for a long period of time in one area during the trip to the operation zone, the mission commander will contact the team to get an update because it is feared that the team is involved in an accident or the vehicle has a breakdown.

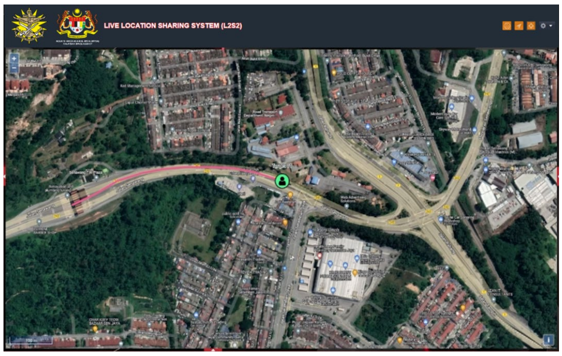

Figure 4. Real-time Movement Monitoring of the Team via Live Routes and Follow Feature.

D. Entering the Geofence and Drone Operation

The notification is sent via an active WebSocket connection in L2S2 when the UAS operation team reaches the operation zone by entering the geofence. In the notification, it will show the time when the team passes through the geofence (Figure 5).

When the team reaches the centre of the geofence, they will start operating the drone within this geofence area. The Traccar Client is also able to be installed on Android-based drone controller. Thus, the time and location of the drone's controller can be obtained and shown in L2S2. Therefore, an estimated time when the drone has been operated can be obtained in L2S2. After the UAS team finishes acquiring data in the current area, they will notify the mission commander and move to the next operating area.

This system is also suitable for multiple team drone deployments. The system will show all teams locations and multiple geofences in the L2S2 basemap as shown in Figure 6. Thus, the mission commander is able to see the location and movement of all deployed teams, which can help the mission commander coordinate the UAS team's movements and deployment. Therefore, the overlap of operational areas during the deployment of UAS teams can be avoided and will not happen.

Thus, based on the simple acquisition of location information that can be displayed in L2S2, team coordination for multiple drone team operations can be done and implemented for rapid assessment or search and rescue during monsoon flood operations. This is because we are able to know the current location of each assigned drone team, and we can deploy the drone team that is closest to the flood victim's location that has been reported to the operation room.

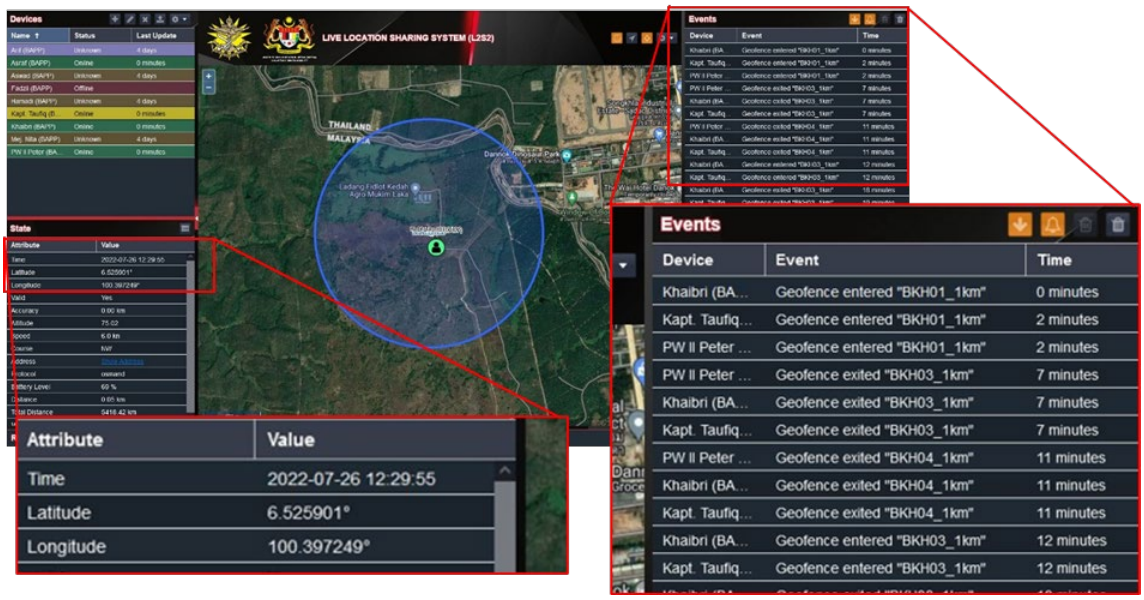

Figure 5. Geofence Notifications & UAS Team's Current Coordinate.

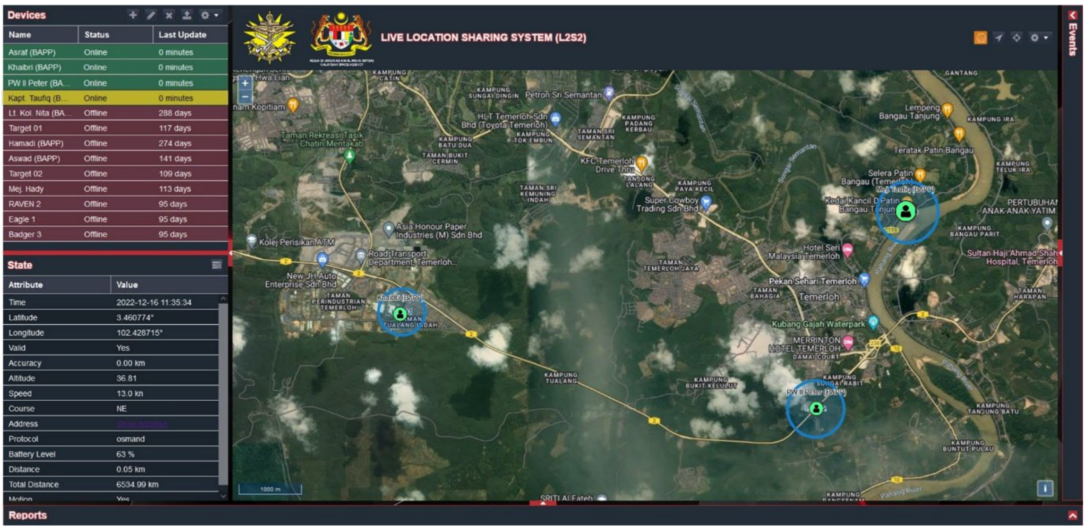

Figure 6. Multiple Drone Deployment Coordination.

V. CONCLUSION AND WAY FORWARD

Although UAS provides a lot of convenience and advantages to humans, especially to reach areas that cannot be reached by human physical capabilities, the level of trust of the general public and the aviation governing body towards the security and safety aspect is still debatable. However, with the existence of L2S2 as a tool for transparency and confidence-building measures in Unmanned Aircraft Systems (UAS) operations, this perspective can be seen to be changed. L2S2 with its unique advantages and capabilities is seen to be the game changer in the landscape of UAS operational management in the near future. Although L2S2 was originally designed for the use of UAS operational management, it is seen as having the potential to be expanded to other applications, such as logistics management and flood relief, which is one of the natural disasters that hit most countries around the world every year.

VI. ACKNOWLEDGEMENT

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