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Utilization of Artificial Intelligence on Unmanned Aerial Vehicle (UAV) to Improve Optimization of Implementation of Border Area Supervision of the Unitary State of the Republic of Indonesia

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Abstract— The vast border area of the Unitary State of the Republic of Indonesia makes this a risk factor that can threaten the security and defense of the country. There needs to be an effective effort to be able to carry out security and supervision of border areas in order to guarantee state sovereignty. In this study, an analysis was conducted on the use of artificial intelligence on Unmanned Aerial Vehicles (UAV) to overcome the limited ability of TNI personnel to patrol border area surveillance. Artificial intelligence in UAV can provide benefits and advantages in terms of effectiveness and efficiency by applying technology that has capabilities in weather forecasting, path planning and obstacle detection, object detection, and energy and power autonomous refueling. Through the innovation of the application of this technology, it is hoped that the use of UAV can optimize security operations and border area surveillance.

Keywords— Artificial intelligence, Unmanned Aerial Vehicle (UAV), Border surveillance.

I. INTRODUCTION

Based on Law of the Republic of Indonesia Number 34 of 2004 concerning the Indonesian ARMY (TNI), that the TNI is a defense tool of the Unitary State of the Republic of Indonesia (NKRI) which is tasked with carrying out state defense policies to uphold state sovereignty, maintain territorial integrity, and protect the safety of the nation, carry out military operations for war (OMP) and military operations other than war (OMSP), and actively participate in regional peacekeeping tasks and international. Based on Article 7 paragraph (1) of Law No. 34 of 2004, the main task of the TNI is to uphold state sovereignty, defend the territory of the Republic of Indonesia based on Pancasila and the Constitution of the Republic of Indonesia Year 1945, and protect the entire nation and all Indonesian bloodshed from threats and disturbances to the integrity of the nation and state. The main task is

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carried out through OMP and OMSP, the implementation of the main task through OMSP consists of 14 types of CSOs, one of which is securing the border area of the Republic of Indonesia. The Republic of Indonesia according to Article 25a of the Constitution of the Republic of Indonesia Year 1945 is an archipelagic country characterized by the archipelago with its territory and boundaries and rights stipulated by law. The boundaries of the state on land, waters, seabed and the land below it and the air space above it are determined on the basis of bilateral and/or triliteral agreements on land, sea boundaries, and air boundaries, as well as based on laws and regulations and international law. According to Article 6 paragraph (1) of Law of the Republic of Indonesia Number 43 of 2008 concerning State Territory, the territorial boundaries of the Republic of Indonesia on land are directly adjacent to the territory of Malaysia, Papua New Guinea, and Timor Leste. While in the sea bordering the territory of Malaysia, Papua New Guinea, Singapore, and Timor Leste, and in the air follows the country's sovereign boundaries on land and at sea, and its boundaries with outer space are determined based on the development of international law. Indonesia's vast territory increases the risk of threats to the country's defense, especially border areas that are not well supervised. This must be anticipated by the TNI to prevent potential threats that can occur. Therefore, there is a need for technology that is able to reach these border areas effectively and efficiently. One technology that can be used to conduct surveillance of border areas is Unmanned Aerial Vehicle (UAV) technology. UAV is a unit of aircraft flight system without human crew, which is controlled remotely either manually or automatically which consists of unmanned aircraft, payload, human resources, control systems, data networks, and supporting elements. However, until now the use of UAV still has limitations in operation such as problems in flight endurance, autonomous flight, limited flight time, and accuracy in determining flight paths (Mohsan et al., 2023). Facing these limitations, it is necessary to have alternative solutions to be able to overcome existing problems. One technology that can be a solution in overcoming these limitations is through the use of artificial intelligence. Artificial intelligence is a field of computer science that focuses on developing computer systems that are able to perform tasks that generally use human intelligence. Artificial intelligence can include the use of algorithms, computing, and data to develop computer programs that can understand, learn, adapt, and perform tasks such as pattern recognition, decision making, problem solving, and so on.

Faced with several limitations of UAV in conducting operations for the benefit of surveillance of border areas, artificial intelligence can be a solution to solve the problem of these limitations. So that in this study, an analysis was carried out on the use of artificial intelligence in UAV with the aim of monitoring border areas. The question of this research is "How is the use of artificial intelligence in UAV to improve the optimization of the implementation of surveillance of the border areas of the Republic of Indonesia?"

II. RELATED WORK

2.1 Artificial Intelligence

Artificial intelligence is an application and instruction related to computer programming to do something that in a human point of view is intelligent or can be understood as a study of how to make computers able to do things that can currently be done better than humans (Tjahyanti, Saputra, and Gitakarma, 2022). Meanwhile, according to McCarthy (2007), artificial intelligence is a special science and technique for creating complex computer programs, especially in creating intelligent computer programs and applications. Through these two definitions, it can be concluded that artificial intelligence is a system or program that has a level of intelligence resembling humans so that it can do the work done by humans. There are four approaches in artificial intelligence technology, (Russell and Norvig, 2010), which include: thinking humanly, thinking rationally, acting humanly, acting rationally.

2.2 Unmanned Aerial Vehicle (UAV)

UAV is an aerial vehicle that is controlled to carry out certain missions/purposes without direct human intervention (Mohsan et al., 2023). UAV can be operated remotely through various electronic devices such as microprocessors and sensors (Nourmohammadi, Jafari, and Zander, 2018). This technology is an unmanned aircraft that can operate automatically and is generally used in a limited area and tends to operate in areas that are not easily accessible by humans. But basically, the operation of UAV still requires control from humans during the activation process.

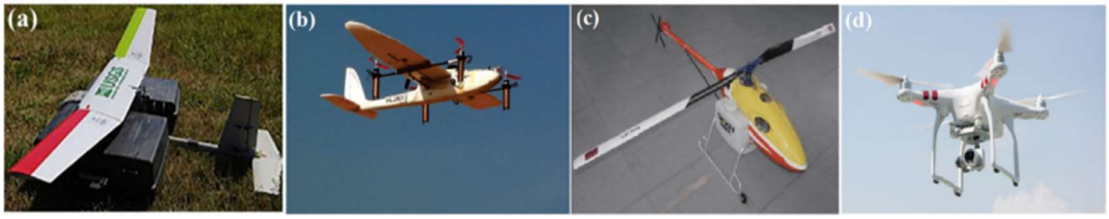

Fig. 1.Fixed wing (a), fixed wing hybrid (b), helicopter (c), multicopter (d)

Source: (Mohsan et al., 2023)

Based on the type of UAV, the following Table 1 is the characteristics of each UAV compared based on energy efficiency, flight system, landing, autonomy, hovering, power supply, endurance, payload, and weight.

TABLE I. CHARACTERISTICS OF THE TYPES OF UAV

Characteristic	***Fixed Wing***	***Rotary Wing***	***Hybrid***
Energy efficiency	Height	Low	Height
Flight system	Complex	Simple	Complex
Landing	Conventional	Vertikal	Vertikal
Autonomy	No	Yes	Yes
Hovering	No	Yes	Yes
Power supply	Battery, fuel	Battery	Battery, fuel
Endurance	60 – 3000 m	6 – 180 m	180 – 480 m
Payload	1000 kg	50 kg	10 kg
Heavy	0.1 – 400.000 kg	0.01 – 100 kg	1.5 – 65 kg

III. RESULT AND ANALYSIS

3.1 Border Area Problems

In development, the border area serves as the front gate of the Republic of Indonesia. Because of its strategic location, ensuring the security of border areas is one of the top priorities in achieving national resilience. Reviewing monitoring of border security in land routes, currently the implementation of security of border areas is carried out through operations and patrols of national borders by establishing integrated security posts. These security posts need to be supported by adequate defense equipment and infrastructure. But in its realization, the posts currently built do not have standards and equality in terms of development. Therefore, this is one of the obstacles in the implementation of supervision carried out. Given that the vast national borders on land routes are one of the challenges for the task force that is joined, there is a need for alternative solutions to be able to carry out the task optimally. Based on Pasaribu, Anwar, and Bonar (2017), some of the obstacles or problems that have been faced to date in carrying out supervision of the border areas of the Republic of Indonesia are:

a. The support of infrastructure and equipment used to carry out surveillance in border areas is inadequate when compared to the extent of coverage areas that must always be monitored and secured.

b. Land area surveillance patrols, especially in some border areas, cannot take place optimally because they are still carried out conventionally by motorized vehicles or on foot in fairly varied and heavy terrain.

c. Monitoring of earth images through satellites run by the National Institute of Aeronautics and Space (LAPAN) although using high-resolution cameras but less effective if the weather is bad and cannot be used for observation and detection of

moving objects such as human movements, vehicles, and so on.

d. Although some land border security posts manned by TNI AD soldiers have been supported by tactical UAV, their use is still unable to monitor the area for 1 x 24 hours and its range is limited.

3.2 Problem Solution

To overcome the problems described above and to improve the optimization of the implementation of border area security operations, the use of the latest technology needs to be implemented so that it can answer the problems and limitations currently faced. UAV as a technology in the form of unmanned aircraft can be used in the implementation of patrolling the boundaries of the Republic of Indonesia. In its development, currently UAV are used to carry out various purposes in military activities and operations. UAV can be used as a means of defense or attack on objects on the surface. UAV have advantages in operation because UAV are not limited by human performance or physiological characteristics. Its ability and capability in carrying out extreme maneuvers makes UAV often used for military purposes. In border security operations, of course, TNI personnel who carry out these operations have limitations such as fatigue or limited physical capabilities, but with the implementation of UAV, this problem can be overcome. The ability of UAV that can monitor in real time and continuously is also one of the advantages of this technology in monitoring border areas by air. On this basis, in the military field, unmanned aircraft (UAV) has become an iconic weapon in modern warfare and even an alternative in the development of weapons of war. UAV can fly and be remotely controlled or programmed to hit specific targets and are equipped with cameras, sensors, communication devices, and other supporting devices. Medium Altitude Long Endurance (MALE) and High Altitude Long Endurance (HALE) UAV are two types of UAV systems used for surveillance with a longer duration. The typical MALE UAV system flies at an altitude of 25,000 to 50,000 feet and can stay in the air for up to 24 hours. HALE systems can fly at altitudes of up to 60,000 feet and can last up to 32 hours (Zwijnenburg and Postma, 2015). The use of UAV can basically be an appropriate alternative, as well as in line with the application of the Revolution in Military Affairs which includes achieving Network Centric Warfare (NCW). The ability of UAV to carry out national territorial surveillance by air with advantages such as aspects of altitude, flexibility and range, minimized operating risks, and the ability to fly for long periods of time, are considerations to be used as defense equipment.

3.3 Utilization of Artificial Intelligence in UAV

In addition to the advantages of using UAV, there are disadvantages that it has including limitations in weather stability, limited remote control, motion detection, limitations of navigation and sensing. In line with the problems and limitations of UAV capabilities, the use of artificial intelligence is an alternative and solution that can be applied to UAV. Based on Marshal (2020), the application of UAV using artificial intelligence allows UAV to operate independently and make their own decisions. The use of artificial intelligence can help humans (UAV pilots) in facing complex challenges. The application of artificial intelligence in UAV includes machine learning, deep learning, and motion planning as shown in Figure below.

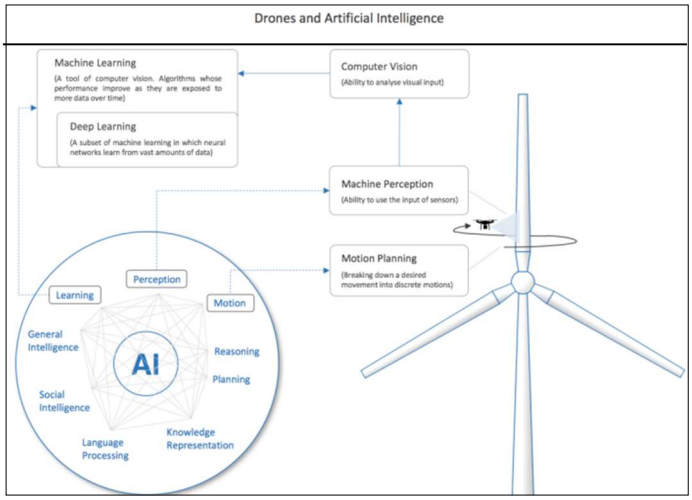

Fig. 2. Artificial intelligence and UAV
Source: (Marshal, 2020)

The use of machine learning is used to optimize the UAV's ability to analyze and learn on its own from the data obtained during the UAV operation (during flight). UAV processes data input so that further data can be analyzed as advanced input material in making decisions. This application can be outlined in technology with weather forecasting features, path planning and obstacle detection, object motion detection, and energy and power autonomous refueling.

a. Weather Forecasting

Research conducted by Moshin, Rahman, and Islam (2019), developed UAV technology that can function as weather forecasting by utilizing artificial intelligence. The technology can be used for real-time and continuous weather monitoring. The device can calculate temperature and humidity so that it can predict the weather from one location to another accurately and quickly. Machine learning such as neural networks, deep learning, and ensemble methods can be used to analyze complex weather data and make more precise predictions. The limitations of UAV in bad weather cause the functionality, balance, and stability of UAV to be disrupted. The presence of rain, lightning, and strong winds can disrupt UAV flights and can potentially cause damage to the system. Bad weather conditions cause UAV visibility to be compromised, so UAV cannot capture aerial shooting images clearly. Bad weather can also increase electromagnetic interference that can affect GPS performance and UAV communications. Therefore, with the weather forecasting feature, it can overcome the limitations of UAV in unfavorable weather so that UAV can analyze the surrounding weather and if the weather is not good or endangers the UAV, the UAV will provide a self-decision to return to ground base automatically.

b. Path planning and Obstacle Detection

Path planning is a process resulting from artificial intelligence technology to plan and obtain an optimal and safe path for UAV to achieve certain goals. Artificial intelligence leverages data received from sensors such as GPS, LIDAR, and cameras to understand the surrounding environment and find the best path that minimizes risk and maximizes efficiency. Examples of path planning algorithms that can be used are A-star or PRC (Rapidly-exploring Random Tree Star). To oversee the security of border areas, UAV can maneuver at altitudes that are quite low, medium, or adapted to terrain conditions, so that in land border areas that have quite difficult terrain will be a limitation of UAV and UAV pilots in controlling and anticipating obstacles and challenges in the area. Therefore, to prevent the risk of falling UAV due to being hit by hills / trees or certain objects, it is necessary to have object detection and path planning features so that the risk of being hit by UAV with objects will be smaller. This will make it easier for pilots to monitor the image / video data sent. With this feature, the UAV is able to maneuver dynamically and flexibly to avoid objects around it.

c. Object Motion Detection

Object motion detection is the application of artificial intelligence into UAV by utilizing the integration of sensors, image processing technology that aims to detect, track, and monitor the movement of objects (specifically humans or moving vehicles) either on land, sea, or in the air. This technology is equipped with special sensors and cameras such as visual cameras or thermal cameras that can collect data through photos and videos. Sensors such as LIDAR can also be utilized to detect human movement in various light and weather conditions. Image processing is then processed by a UAV system that can identify the object and can transmit it to the ground base (station). This is useful for surveillance in border areas because of the wide range of border areas, technology is needed that can effectively identify the movement of objects in this case humans or vehicles in the border area. This capability can overcome the limitations of the TNI charm if it has to carry out conventional patrols that require considerable resources both time and energy and have high risks. The UAV can identify movements that are indicated to be illegal movements so that it can in real time send them to ground stations.

d. Energy and power autonomous refueling

Energy and power autonomous refueling capability is the ability of UAV to independently refuel or source energy without human intervention and control. This feature is important for UAV to have, especially in missions that require long flights and continuous monitoring. The fuel system must support to be able to carry out real monitoring continuously, alternative fuels that can be used are batteries or hydrogen fuel cells. UAV with this capability must have

sensors to be able to monitor the remaining fuel or energy levels. The smart control system can be used to adjust the refueling process based on mission needs and mileage. The working system of this technology is with the principles of detection, navigation, and refueling. In the detection process, the system can predict the remaining time compared to the available fuel and plan automatically for the most efficient regulation and selection of the travel path to reach the fueling station. Furthermore, the navigation process will ensure the movement of the UAV to be able to cross effectively from a predetermined route / path by considering the appropriate speed and altitude. After getting to the fueling station, the UAV will perform the refueling function automatically. This technology can answer the problem of running out of fuel in the middle of a mission during flight which can cause UAV to lose contact and be lost. This technology can make it easier for UAV pilots to organize and plan navigation for refueling purposes, so that pilots do not experience difficulties in the process of predicting and planning paths and fuel during fuel emergencies.

IV. CONCLUSION

To be able to realize security operations against border areas using this technology, it is necessary to have a role and government policy taken in the process of research and development (research and development) artificial intelligence to encourage academics, scientists, and artificial intelligence experts to always innovate in creating these technologies that can be used to support national defense. In addition, there needs to be collaboration and integration between agencies to jointly develop artificial intelligence technology in UAV that are more sophisticated and answer the progress of the times.

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