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***Abstract*—Unmanned Aerial Vehicles (UAVs) have a variety of usages. One of the way to use is replacing the role of military aircraft. Conducting assault missions with UAVs reduces life threatening risks to military personnel and is a cost effective alternative. In addition to conducting assault missions, UAVs are also used as a defense mechanisms against enemy UAV attacks. Several research that uses radar or image processes to identify whether an object is UAVs or not, however, misjudging issues commonly occur. This paper suggests a method to get accurate information about the object that is detected by radar. The proposed system utilizes a drone to physically chase the object.The radar results of the object, which are used to predict its trajectory, is fed into the prediction model which included in chasing algorithm. At the end of the algorithm, the distance between the unidentified object and a friendly drone closes, which helps to identify if the object is an enemy UAV or not without the use of high-quality camera lenses.**

***Index Terms*—UAVs, detection, chasing, trajectory prediction**

I. Introduction

Unmanned Aerial Vehicle(UAV) has a great diversity of use including agriculture, security, delivery, and also in the military. In the case of the military, Military aircraft have two categories, non-combat and combat roles. Non-combat aircraft are used for reconnaissance, surveillance, and transport. Combat aircraft are used in air-to-air combat, carrying bombs for ground attack and so on [1]. Using UAVs as military aircraft has the advantage of reducing life threatening risks to military personnel. Another benefit is the cost and labor, UAVs are cheaper to produce and maintain. In Ukraine - Russia war, UAVs take part in and strike other territories to destroy the installation [2]. Conducting a mission with UAVs is now normal.

On the other hand, the challenge to prevent UAV attacks still persists due to the accuracy of the process of detecting, tracking, and eventually shooting down the UAVs. In the detection process, multiple papers state they use radar to detect drones and classify them. Recurrent Neural Network-based Frequency Modulated Continuous Wave radar makes detecting works in real-time. The experiment recorded a false detection rate of 21.1% and a detection accuracy of 96.4% [3]. Another approach is to use You Only Look Once(YOLO) to classify it. YOLO is an object detector which performed detecting an object in an image as a regression problem. The whole detection pipeline is a single network, it is faster than the old approach [4]. With a YOLOv3, The pre-trained machine learning model had an average accuracy of 88.9% at input image [5]. Although a lot of work is conducted to detect drones, Using partial data to identify an object can cause false detection, leading to disaster. on Dec 26, 2022, 5 North Korean(NK) drones entered the no-fly zone in South Korea(SK). SK noticed NK drone entered on Jan 3, 2023. NK drones were detected by radar but lack of information. They were misjudged as birds or balloons [6]-[8].

The best way to identify if the drone is hostile or not is to take an up-close picture. Hostile drones tend to be armed with weapons or not verified in a database.

INSERT PICTURE (weaponized drone picture compared to normal one).

There are two ways to make this distance closer. The first method uses a camera that has the ability to zoom in at any distance clearly. This method is unpopular because of the high cost. An alternative method uses a good drone to chase the Unidentified Drone(UD), this allows for an up-close clear picture. Predicting the next location of the good drone and UD is important. Relevant data used for location predictions include altitude, longitude, latitude, and vector which are combinations of speed and direction. In general, RAdio Detection And Ranging(RADAR) locates an unidentified object in the sky. Vector is obtained by 2 location results from RADAR. Locations and vector results feed into (Linear regression / Long-short term memory) model to predict the next location. The latency of receiving commands from a computer to a drone is a hyperparameter to control.

INSERT CHART (chart DJI drone has a 76% in drone market)

As DJI, the Chinese company dominates the drone market, their products becomes more of a threat [9], [10]. In this paper, DJI's drones are the object to predict the next location. Location and vector data from the drone is exported from the interface which was implemented with DJI mobile Software Development Kit(SDK). The (Linear regression / Long-short-term memory) model predicts the next location of fed data. Performance is measured with the accuracy of the next location at n(with italic) sec and the ratio of the reduced distance compared to the previous one. Closer distance gives the advantage to take a better picture to identify the drone. Moreover, If the Time Space-Position Information(TSPI) of an unidentified object is earned, the method fits in a general way.

II. Related Work

UAVs is through friendly RADAR. RADAR is a radiolocation system that utilizes radio waves to determine the distance, angle, and velocity of objects relative to the site. However, A major disadvantage to RADAR is the classification of identified objects. To solve this problem, Kim Seung-woon and Ho Seok Jang proposed using Light Detection and Ranging (LiDAR) to detect UAVs [11]. LiDAR is a method for determining ranges by targeting an object or a surface with a laser and measuring the time for the reflected light to return to the receiver. They gained higher accuracy by using LiDAR rather than the existing radar system. Although LiDAR is more efficient at detecting drones, it is more expensive and is susceptible to certain weather conditions. So, this paper proposes a method of recognizing an object by using the existing RADAR system and predicting the object's future trajectory using the past TSPI of the object with (Linear Regression / Long Short-Term Memory(LSTM)). While using this method, it is important to calculate the spatial coordinates from the RADAR system, and to consider the relation between past TSPI and trajectory prediction. Knowing the machine learning we use is also essential. Because trajectory prediction is obtained by Using (linear Regression / LSTM). This section surveys previous studies addressing these points.

A. calculating spatial coordinates

Distance calculated from RADAR to a detected object can be converted to relative coordinates. Han-Seop Shin *et al.* proposed relative coordinates from the RADAR are converted to new relative coordinates from another object [12]. To conduct this, they used the formula about rotation matrix and transpose matrix with Cartesian coordinates. This process also involved finding the astronomical coordinate system of RADAR and other objects such as their longitude, latitude, and altitude. It has a chance to derive absolute coordinates about the detected object.

B. Relation between past TSPI and trajectory prediction

Ziyu Zhao *et al.* focused on aircraft trajectory prediction using deep learning with Trajectory Change Point (TCP) [13]. TCP is created by using a trajectory clustering algorithm and analyzing the relationship between meteorological information like the average geopotential height (meter), average temperature (Celsius), wind direction (square degree), and past data including longitude, latitude, altitude, and velocity. TCP is used to know aircraft intention. Depending on the weather, aircraft direction has a possibility to change. They utilized mixture density Long Short-Term Memory (LSTM) to apply to the probability distribution of aircraft trajectory. because factors of uncertainty such as airspace environment, and pilot factors exist. As a result of performance evaluation like European distance Error (EE), trajectory prediction in this paper was more accurate than previous studies. Although the paper was based on aircraft, it is worth applying to UAVs since the difference between them is only the presence or absence of a person on board.

Xie Lei *et al.* wrote a paper under the theme of Unmanned Combat Aerial Vehicle (UCAV) maneuvering trajectory prediction in Particle Swarm Optimization-Convolution Neural Network (PSO-CNN) [14]. They used three control variables such as throttle, angle of attack, and roll angle. The spatial coordinates information like longitude, attitude, and altitude can be derived by using relational expression including control variables. They proposed trajectory prediction with a suitable Convolution Neural Network(CNN) model. CNN has an input layer, hidden layers, and output layer. each of the layers has a weight value. When the weight value is updated by backpropagation, The problem called gradient disappearance has a possibility to happen. However, PSO-CNN can avoid this problem because it uses a heuristic optimization algorithm to transform the weight update into an optimization problem. Compared to other methods such as LSTM, Adaboost-BackPropagation(BP), CNN, the method used in the paper produced better performance.

Another paper conducted by Peng Shu *et al.* mentioned the trajectory prediction of UAV based on LSTM [15]. They used 3-dimension past data like longitude, latitude, and altitude in UAV trajectory time series data. These data were used as input values by Stacked Bidirectional and Unidirectional LSTM (SBULSTM). SBULSTM is composed of unidirectional LSTM layers, Bidirectional LSTM (BLSTM) layers, a full connection layer, and a dropout layer. By using BLSTM, not only related past data but also related future data is considered. They made the model using SBULSTM and get high accuracy in trajectory prediction What these three papers have in common is having the capability to predict trajectory utilizing past data. Through these three papers, it can be seen that TSPI is worth using as data necessary for trajectory prediction.

C. LSTM / Linear Regression

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