Proceedings of the Seventh International Conference on Research in Intelligent and Computing in Engineering pp. 25–27
DOI: 10.15439/2022R46
ISSN 2300-5963 ACSIS, Vol. 33

Navigation for drones in GPS-Denied environments based on Vision processing

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***Abstract*—This paper presents a method for the navigation of drones in GPS-denied Environments based on vision processing. A camera is attached to the drone to fly in full conditions like GPS, video streaming, control waypoint, etc. Then, some information such as the image features and location of the drone is extracted and stored, which is used for the next flight with GPS-denied Environments. The results are shown that the drone positions could estimate with high accuracy.**

***Index Terms*—UAV, GPS-Denied, vision**

I. Introduction

Unmanned aerial vehicles (UAVs) have known as useful robotics and have many applications such as in the military [1], agriculture [2], transportation [3], etc. To effectuate these tasks, UAVs must be developed and tested many times under different conditions. For example, the structure designing process needs to be evaluated by the NX software [4], and the Heritage Building Information Modeling [5]. Besides, the flight control system (FCS) is also considered in detail with the hardware layer and software (algorithm) layer.

Some hardware was suggested as DJI [6], pixhawk [7], etc. They brought useful values to the UAV development community. For testing software, some researchers used Matlab Simulink to present their UAV model as fixed-wing [8], quadrotor [9], and hybrid [10, 11] with the control algorithms as PID [12], Fuzzy-PID [13], Neural network [14], and sliding mode control [15]. Recently, software in the loop simulation (SILS) is developed to present more details in simulation [16]. All demonstrations showed well results and high performance.

Although UAVs have spent many years of development and application, the approach is to control UAVs following the trajectory and waypoint of the Global Positioning System (GPS). The sensors such as Inertial Measurement Unit (IMU) and GPS are very important for all operations of flight which measures the attitude and location feedback of all controllers.

Normally, the IMU used the estimations and computed the attitude information in local devices. While GPS needs the satellite which is dependent on the service provider. Therefore, GPS could no stable, lost, and denied. This paper presents to detect and computed the location of UAVs in the GPS- Denied conditions using vision processing. Phantom 4 DJI Quad-rotor is selected for demonstrating our algorithms.

II. Experiment setup

In this experiment, the Phantom 4 DJI is used with the parameters in Table. 1.

TABLE I. Phantom 4 DJI specifications

Name	Specifications
Weight	1.38kg
Max speed	20 m/s
Max flight time	28 mins
Satellite Positioning Systems	GPS/GLONASS
Max Service Ceiling Above Sea Level	19685 feet (6000 m)
Camera	1/2.3” CMOS, Effective pixels:12.4 M, FOV 94° 20 mm (35 mm format equivalent) f/2.8

For making the dataset, the UAV is controlled in manual mode. The video capture and mapping are performed in Hoa Binh Park, Bac Tu Liem, Ha Noi, Vietnam. Herein, the mapping is formatted in the tif and geotagged tif file which are tagged locations via the Drone Deploy on PC [17]. The parameter setup of all flights are defined in Table. 2.

TABLE II. Parameter setup for all flights

Devices/Steps	Parameters name	Details
CPU	Operating system	Ubuntu 20.04
	CPU	Intel i5-7500
	RAM	8 GB
Video capture	Resolution	720x1280
	FPS	29
	Times	2m00s (120 s)
	GPS frequency	10 Hz
Mapping	Resolution	9844x9265

III. Detecting GPS location algorithms

Based on the mapping containing the image infomation and GPS-tagged locations, this paper uses the scale-invariant feature transform (SIFT) [18, 19] to match the current vision image with the dataset which is recorded in previous flights. Therefore, the current location of the drone could be computed and given to the drone for safetying flight with no GPS conditions.

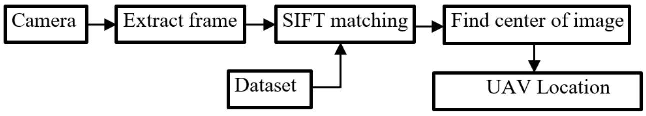

Fig. 1. Find UAV location algorithms

Fig. 1 shows details for finding location of UAV. Firstly, the frame is extracted from camera. They are used to match with all images from dataset which includes location of UAV in last flight by using SIFT algorithm. If the number of feature matching is larger than a threshold values (15 features), the algorithm will select this image for finding the center of image and it could present to UAV location because all images are capture from UAV and UAV is a center of viewing as our configurations.

IV. Results and discussion

Using the algorithm in Sect. 3, the UAV flight is performed and the results are shown in Fig. 2 and Table. 3 and 4.

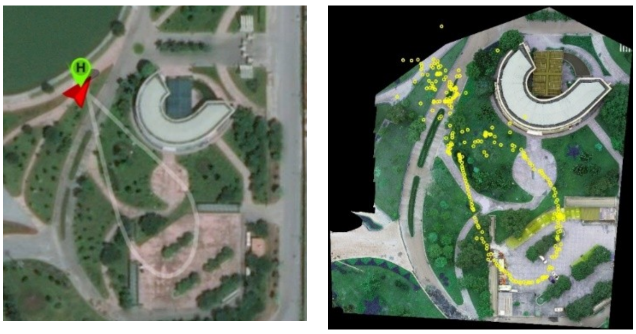

Fig. 2. Comparation between previous flight and the current flight

As the description in Sec. 2, a PC is used to detect the location of the UAV. The specification is CPU Intel i5-7500, 8 GB RAM, and OS Ubuntu 20.04. To improve the speed of algorithms, the map in the dataset will be re-scale to create a small size file and it is also applied to the images in the current flights. Let's define these parameters as map_scale and uav_scale.

In this experiment, the map_scale and uav_scale are adjusted to check the performance of the algorithms. Table. 3 and 4 present the different output in each case.

TABLE III. Result with diffrent map_scale

No.	map_scale	uav_scale	Matching %	Error locations (m)	Time processing (s)
1	5%	25%	70.27%	3.72 m	49.45
2	10%	25%	74.16%	3.04 m	112.54
3	20%	25%	69.16%	2.73 m	353.16
4	33.33%	25%	61.11%	2.91 m	925.7

As the results in Table. 3, the adjusted map_scale is not bearing to ratio matching, but the accuracy of location estimation could be improved. The large scaling needs a long time for processing. In Table. 4, the uav_scale is really affected to the matching. It leads to the performance of the finding the location UAV. To integrate on the UAV, the Nvidia Xavier board will be used and all scales are considered again in the future works.

TABLE IV. Result with diffrent map_scale

No.	map_scale	uav_scale	Matching %	Error locations (m)	Time processing (s)
1	10%	12.5%	22.22%	3.07 m	86.73
2	10%	25%	74.16%	3.04 m	112.54
3	10%	50%	96.38%	2.26 m	190.84
4	10%	75%	98.33%	2.72 m	324.65

V. Conclusion

This paper presents an experiment related to estimating the location of UAV in GPS-Denied environment using vision processing which could help navigation for the UAV. Based on Phantom 4 DJI, the mapping and location are tagged and store in a dataset which is used to match with the current frame from camera on UAV for next flight in no GPS condition. The matching process is applied by SIFT algorithm. All results are shown that the proposal algorithm could compute the location and help navigation for UAV.

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