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RESEARCH ARTICLE - ENGINEERING

Object Tracking with the Drone: Systems Analysis

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Abstract

The fast improvement in computer vision and the increase in the range of its application around the world. And at the same time the improvement of unmanned aerial vehicles (UAV). The computer vision application is being integrated with the drone to achieve several purposes. one computer vision application that is used with the drone is object tracking. This type of task is used with the drone to achieve semi-autonomous movement of the drones, depending on the movement of the pre-determined target. This work categorizes the two methods to design object tracking by drone.

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1. Introduction

In recent years, there are fast development in computer vision the reason for that is its wide range of applications like surveillance systems, robots, drones, and many others. Computer vision has several tasks image object detection, video object detection, single-object tracking, and multi-object tracking [1]. In recent years computer vision applications are used with the drone to achieve purposes. These purposes include delivery [2], avoiding obstacles [3], controlling more than one plane [4], mapping [5], analyzing forest images [6], farming [7], and others. One of the applications of visual computing used with drones is object tracking. tracking is a big problem in computer vision. Some high-level application like video surveillance requires tracking some objects specified in the first frame to corresponding objects in the next frame [8]. These tracking algorithms are used to achieve semi-autonomous movement of the drones, depending on the movement of the pre-determined target. There are two main methods to design a drone object tracking system. The first one is the traditional method where the drone sends the video to the ground station. for the ground, the station is perform tracking algorithms for a specific target and sends the required signals to the drone to move with the movement of the target. This type is called (off-board processing). the second type relies entirely on the embedded systems without the need for the ground station to perform the smart vision and send tracking signals to the drone. where the tracking algorithm is performed on an embedded system and converts the tracked target location to drone velocity to move the drone with the movement of the target. The problem with off-board processing is the delay in the transmission of video from the drone to the ground station and control signal transmission time from the ground station to the drone. The problem with on-board processing is resources of the embedded system are very constrained. Which is required much processing time to achieve the smart vision. This gives a limitation in using embedded systems with AI applications. And by increasing the applications required for this AI algorithm to run on edge devices without connecting to the cloud the chip designers and many hardware manufacturers start designing edge devices that can execute this algorithm with less processing time. For example, NVIDIA Jetson Nano [9], ASUS tinker board 2s[10], BeagleBone AI[11], and many others. All those designers and companies support these devices with GPU and more memory capacity as shown in Table 1. But NVIDIA supports your embedded devices with hardware and software that can accelerate the processing speed more than other devices. For example, the NVIDIA Jetson nano which is come with GPU and multi-core CPU, and high-speed RAM, NVIDIA supports it also with a JetPack framework that is designed especially for this device. JetPack includes the latest NVIDIA tools for application development and optimization. like Deep Stream, TensorRT, cuDNN, and Computer Vision VPI (Vision Programming Interface), and also can use the Cuda toolkit that can parallelize the GPU cores to execute the NN.

Nomenclature & Symbols			
UAV	Unmanned Arial Vehicle	CNN	Convolutional Neural Network
AI	Artificial intelligent	NN	Neural Network
GPU	Graphical Processing Unit	VPI	Vision Processing Interface
CPU	Central Processing Unit	CuDNN	Cuda deep neural network
OpenCV	Open Computer Vision library	PID	Periportal Integral and Derivative controller
FPS	Frame Per Second		

Table 1. Embedded GPU based system comparison

	Jetson Nano [1]	ROCK Pi N10 [2]	BeagleBone AI [3]	HiKey970 [4]	Tinker board 2s [5]
Company	Nvidia	Radxa	BeagleBoard	Linaro	ASUS
CPU	Quad-core ARM A57 @ 1.43 GHz	2-core Cortex-A72 @ 1.8 GHz and 4-Core Cortex-A53 @ 1.4 GHz	Dual-core ARM Cortex-A15 @ 1.5GHz	Cortex-A73 4-Core @ 2.36GHz and Cortex-A53 4-Core @ 1.8GHz	Quad-core Arm® Cortex®-A53 @ 1.5 GHz
Memory	4 GB / 2 GB 64-bit LPDDR4 @ 25.6 GB/s	4 GB/6 GB/8 GB 64-bit LPDDR3 @ 1866 Mb/s	1 GB	6 GB LPDDR4X @ 1866MHz	Dual-CH LPDDR4 2GB / 4GB
GPU	128-core NVIDIA Maxwell	Mali T860MP4	PowerVR SGX544	ARM Mali-G72 MP12	Arm® Mali™-T860 MP4 GPU @ 800 MHz
Storage	microSD card support	16 GB/32 GB/64 GB eMMC	16 GB eMMC	64 GB UFS 2.1 microSD	16GB eMMC
Price	99$	169$	110$	299$	140$

The main motives of this research are to review previous methods in the use of visual computing with drones and analyze them to determine the best ones. The main contribution of this paper is to divide and analyze the methods used in the use of computer vision with drones and review previous work in this field. Single object tracking was chosen as one of the computer vision applications to be used with drones.

2. Computer Vision with Drone Processing System Types

2.1. Off-board processing system

This section describes the off-board object tracking system. In [14] the researcher as shown in Fig. 1 relies on achieving object tracking by sending the video signal from the drone to the cloud to carry out the tracking process and send the required movement signals to the drone. the researcher designed a high-speed tracking algorithm to increase the tracking speed. What distinguishes this work is the integration of the Internet of things and computer vision with drones. that manage to achieve tracking. But it depends on the Internet, as any defect that affects the Internet stops the work of this system, in addition to exposing this system to penetration when it is connected to the Internet.

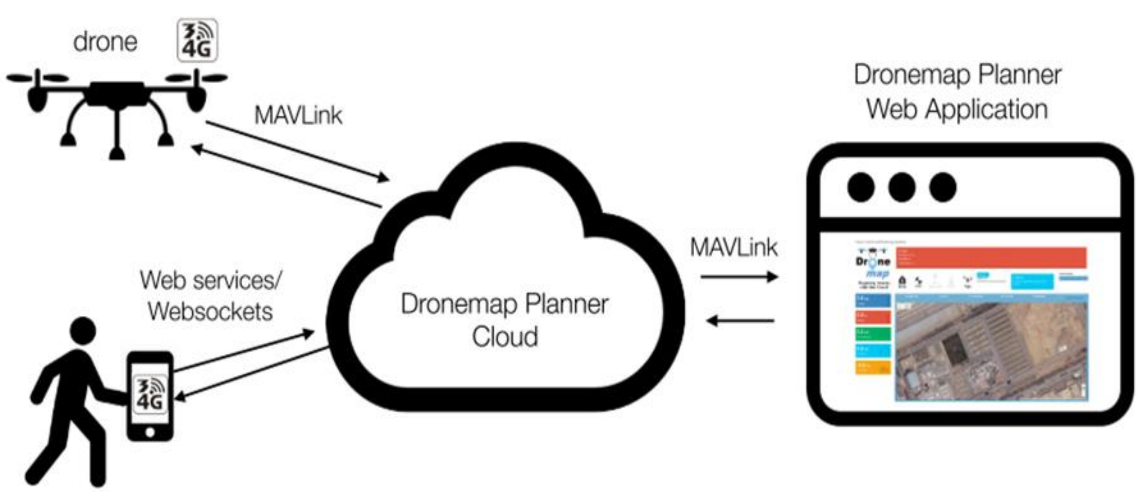

Fig. 1. System data flow [14]

In [15] from system architecture in Fig. 2, the designer sent the video from the drone to the ground station via Wi-Fi to carry out the tracking process using an algorithm that was designed based on CNN networks. The PID is also used to control the movement of the drone according to the detected movement of the target.

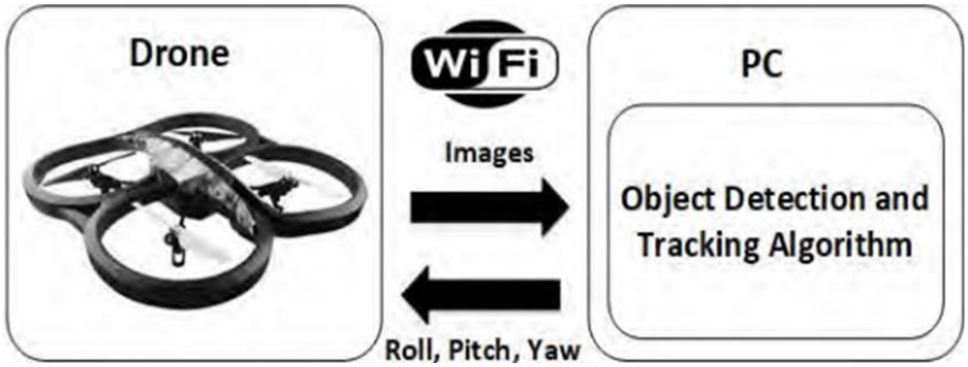

Fig. 2. System architecture [15]

In [16] the researcher sends a video signal from the drone to the ground station to perform the process of detecting and tracking objects using the tiny-yolo algorithm with high speed and accuracy. This research is characterized by the use of the mobile as a ground station to control the drone, where the tracking and control system of the drone was designed to work on the IOS system (as shown in Fig. 3).

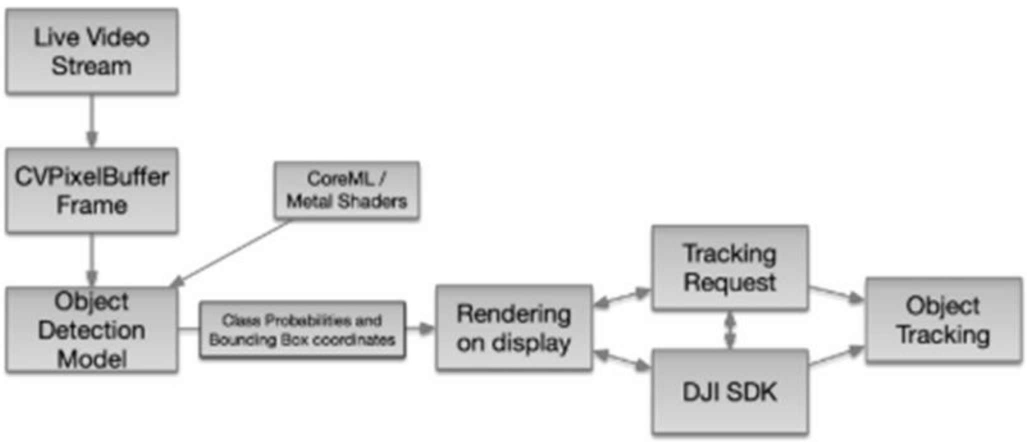

Fig. 3. Implementation blocks [16]

2.2. On-board processing system

This section describes the off-board object tracking system. In [17] the researcher used an embedded system that contains a snapdragon 801 CPU (2.4 GHz) to implement the tracking algorithm. And due to the lack of a graphical processing unit (GPU), the researcher designed a tracking algorithm far from deep learning to achieve speed in execution, based on its design of subtracting the background to discover moving objects, and the execution speed of the designed algorithm reached 16.2 fps. Fig. 4 shows the detailed implementation of this system.

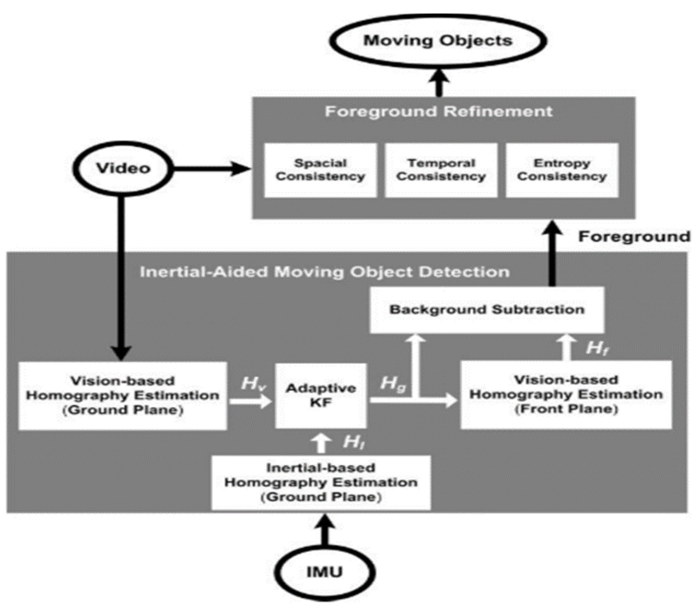

Fig. 4. Basic data flow [17]

In [18] the researcher relies on a more advanced embedded system. NVIDIA Jetson tx2 is an Embedded system produced by NVIDIA company that contains a graphical processing unit to achieve a higher speed in executing tracking algorithms. In addition, the researcher designed an algorithm that relied on increasing the tracking accuracy when the target shape and size changed. Fig. 5 is the diagram overview for this system.

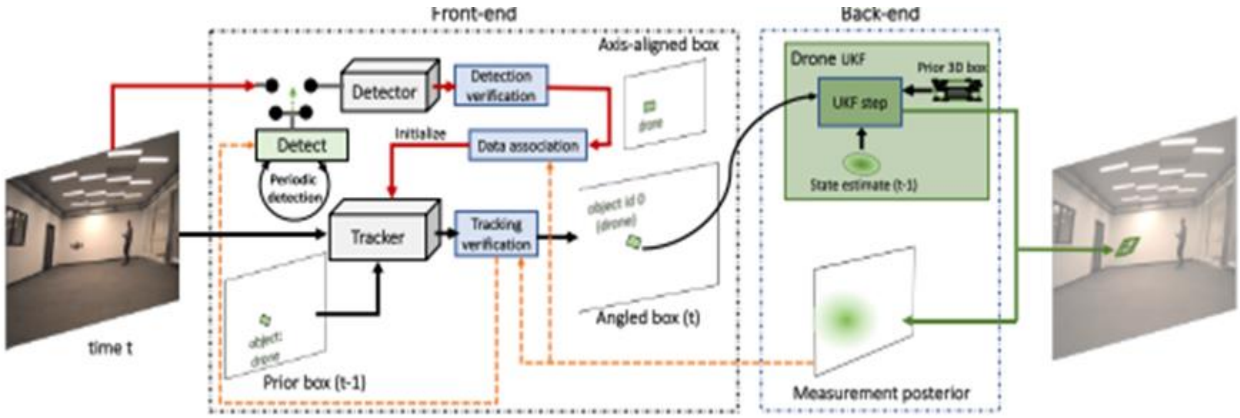

Fig. 5. System overview [18]

In [19] the researcher uses tracking algorithms designed using deep neural networks. And its implementation on more than one type of embedded system that contains a GPU and that does not contain a GPU. Where the researcher concluded that the best alternative to the ground station is the use of NVIDIA Jetson AGX Xavier. which is a high-efficiency and cost-effective embedded system. It can perform artificial intelligence algorithms at high speed.

In [20] the researcher relies on NVIDIA Jetson tx2 as an embedded system used on the drone to implement tracking algorithms. In this work, the researcher used tracking algorithms pre-built in the OpenCV library. The execution speed of these algorithms ranged from 18-72 FPS. Fig. 6 shows the system architecture.

Fig. 6. System architecture [20]

3. Result and Discussion

Previous works of off-board processing used the ground station in the tracking process and control drone. Because of the delay in the transmission and reception of the video and the loss of some data, the researchers turned to use the embedded system with the drone to carry out the process of tracking and controlling the drone. Fig. 7 shows a general diagram for the off-board processing system.

As shown in Fig. 8 in the onboard processing system type most researchers have designed a drone object tracking system that allows a drone to track a specific target using pre-designed tracking algorithms without taking into account the resources constraint of the embedded systems. We can also note that when the researcher aims to increase the speed of tracking algorithms, he goes towards using an embedded system that is more efficient than others. without looking at the method of designing the tracking algorithm.

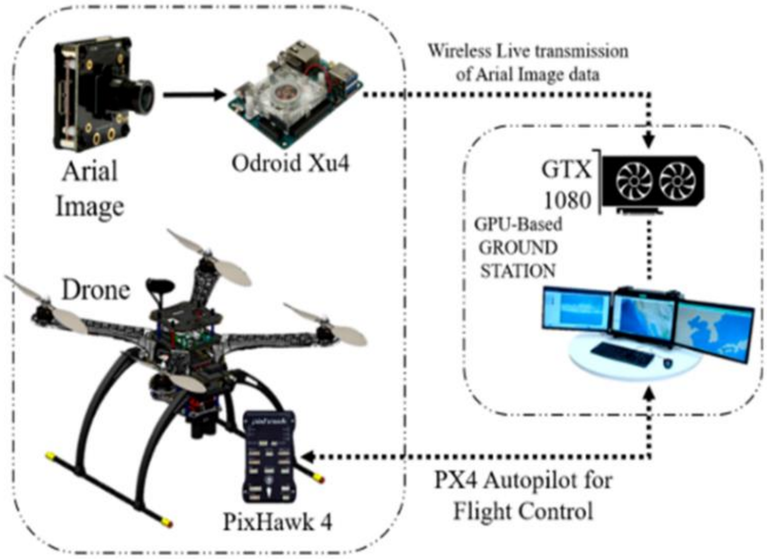

Fig. 7. Off-board processing using the GPU-based ground station [19]

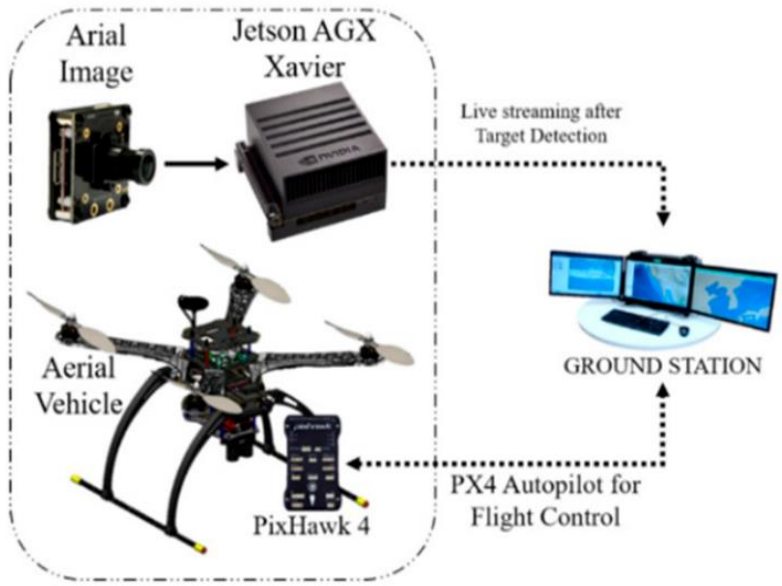

Fig. 8. On-board processing using Jetson AGX Xavier [19]

4. Conclusion

This work describes the two methods used to implement a drone object tracking system. There are two types to design the system. The first one is off-board processing which needs a ground station to perform tracking. And the second one is on-board processing which needs an embedded system connecting with a drone to perform tracking for the object. On board, the processing is the best in designing the system to avoid data loss when transferring to the ground station in the first type. But to achieve the best speed, it is necessary to use an embedded system with high processing capabilities. But the off-board processing is the most efficient in terms of energy savings, as it performs the treatment process in the ground station.

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