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Design And Fabrication Of An Outdoor Quadcopter

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Abstract

The main objective of the paper is to design and fabricate the quadcopter for the purpose of surveillance, tracking and land survey aiding. The ability of the quadcopter is to produce the Unmanned Aerial Vehicle (UAV) based photogrammetric measurements for a defined plot using LabView with image processing techniques. The important feature of the developing this model is that because quadcopter has good flying capabilities to measure the defined plot with the aerial view. This quadcopter can fly at fixed height in air to identify the human to be followed and following the human for tracking purpose using vision based control through live video streaming. A vision based control strategy is used for tracking and following objects using an Unmanned Aerial Vehicle. We have developed an image based visual servoing method that uses only a forward looking camera for tracking and following objects from a multi-rotor UAV, without any dependence on GPS systems. Our proposed method tracks a user specified object continuously while maintaining a fixed distance from the object and also simultaneously keeping it in the center of the image plane. The algorithm is validated using a quadcopter in outdoor conditions while tracking and following people

Keywords — multirotor control, Visual Servoing, Object Following, LabView, image processing, Unmanned Aerial Vehicle (UAV).

I. Introduction

Until recently, Unmanned Aerial Vehicles (UAV) or also often known as drones, were mostly developed and used for military applications. These systems are remotely-controlled aircrafts or helicopters. They are equipped with precision sensors, for example, inertial motion units (IMU) and gyroscopes, for recognizing the alignment and position of the aircraft. A microcomputer makes the autonomous navigation without much manual involvement of a pilot possible. Due to the cost and size of these sensors, a non-military use and especially smaller UAV systems have not been feasible for many commercial applications. With the recent availability of highly accurate and low-cost Global Positioning Systems (GPS), the possibility opened up to maintain a UAV system's position in a global reference system nearly everywhere in the world and in real-time. However, selective availability of such GPS signals had prevented most commercial applications. It was until the mid-1990 when the accuracy of GPS for commercial applications dropped to just a few meters.

With the arrival of precise GPS and gyroscope technology the performance, especially the payload, endurance, and flexibility for diverse and reliable application of UAV systems, significantly improved. Most recently, light-weight digital photo or video cameras converted autonomous UAV systems to highly mobile sensor platforms. However, few applications in civil engineering have yet been fully explored although they promise to provide more cost- and task-efficient ways to conventional approaches. For example, surveying applications are relying mostly on labor-intensive GPS, Robotic Total Station (RTS), laser scanning, and tachymetry. In addition, there are air- or space-borne technologies available, but their selection depends on the terrain and size of the area that must be surveyed. They are limited in range, very labor intensive and costly, have potentially high measurement errors, and are time consuming to perform.

Visual Object Tracking can be a reliable source of information for Unmanned Air Vehicles (UAV) to perform visually guided tasks on GPS-denied unstructured outdoors environments. Navigating populated areas is more challenging to a flying robot than to a ground robot because it requires to stabilize itself at all moments; in addition to the other usual robotics operations. This provides a second objective to the presented work to show that Visual Servoing, or positioning a Vertical Take-Off and Landing (VTOL) UAV relative to an object at an approximate fixed distance, is possible for a great variety of objects. The capability of autonomous tracking and following of arbitrary objects is interesting by itself; because it can be directly applied to visual inspection among other civilian tasks.

The contributions of this paper are the integration of a system that: performs Visual Servoing on a great variety of targets, does not depend on GPS, and is able to achieve person following while handling occlusions. Its success has been achieved through the knowledgeable choice of robust and reliable components, namely: the open-source object tracker OpenTLD and the quadcopter

II. METHODOLOGY

The complete process has been split into different modules starting from design of the UAV, selection of materials and the fabrication of the frame. The system for the overall control of the motors and for the stability of the aircraft in-flight. From Fig. 1 first step consist of Identification of the Quadcopter and its Application. The second step is Designing the Quadcopter. Once the concept is developed for the identified problem, the different possibilities of the concept is sketched out and studied. The optimum solution for the concept is arrived after the studies.

The next step is Procurement of Quadcopter parts i.e, Frames, Motor, Flight Controller Board, Electronic Speed Controllers. Then to fabricate and assembly the quadcopter. Next stage is to implement the application usage in the quadcopter. Then an algorithm is to be developed for the automated control of the Outdoor quadcopter for the purpose of surveillance, human tracking and land survey. And finally, programming the quadcopter for verifying the algorithm is done in multiple trials.

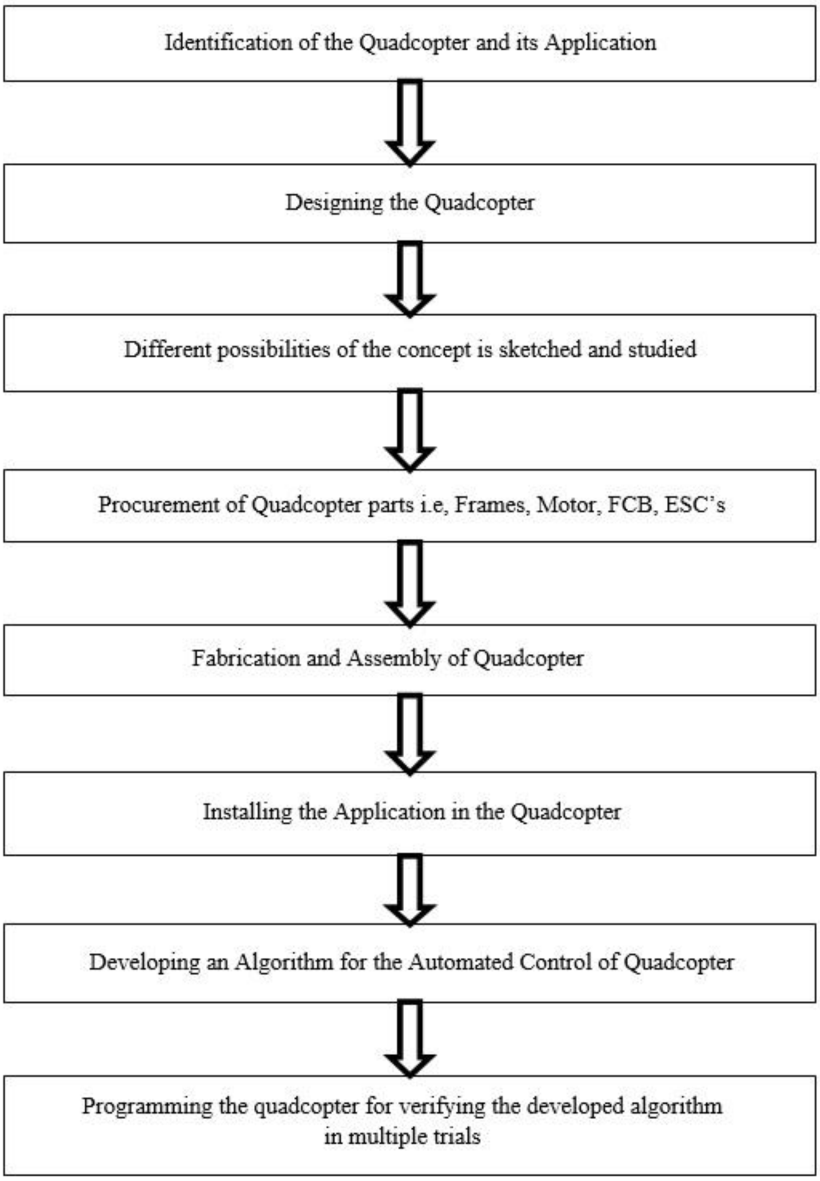


Figure 1 Flow chart of methodology.

III. SYSTEM DESCRIPTION

Our system consists of several modules that can commu-nicate with each other under the Robot Operating System (ROS) framework. The quadcopter is commanded from a computer via WiFi link using the autonomy ROS package to communicate with the Drone. A ground station based on the ROS (Robot operating System) environment will continuously monitor the vehicle and display health and status information during the flight. The vehicle will continuously send information about its pose, velocity, health status, environment (real time images), etc. to the ground station (over a 2.4GHz wireless LAN data link) preconfigured with ROS making it easier to interpret the data received and present it in an informative way.

We can have the capability of automatically controlling the remote system with the aid of a personal computer or any supportive hand held device. The data communication is done through 2.4GHz wifi link to ground station using a wireless NIC (Network Interface Card) onboard operating on 802.11n mode. The ground station node communicates among them through a separate adhoc wifi link. For safety pilot/ kill switch a separate 2.4 GHz RC link is used with an onboard receiver interfaced with flight controller.

From Fig. 2 and Fig. 3 below the system uses a three cell Lithium polymer Ion battery. It provides power to motors, onboard processor, sensors and video camera. The battery has power rating of 2x1500mAh which gives of 36 minutes on air. The flight controller 1GHz 32 bit ARM Cortex A8 processor with 800MHz video DSP TMS320DMC64x has an on board battery eliminator circuit (BEC). The BEC takes care of controlled descent in the event of low battery. The quadcopter has 4 brushless in-runner motors of 14.5W with 28,500 RPM and the frame is made out carbon fiber which weights below 400 grams.

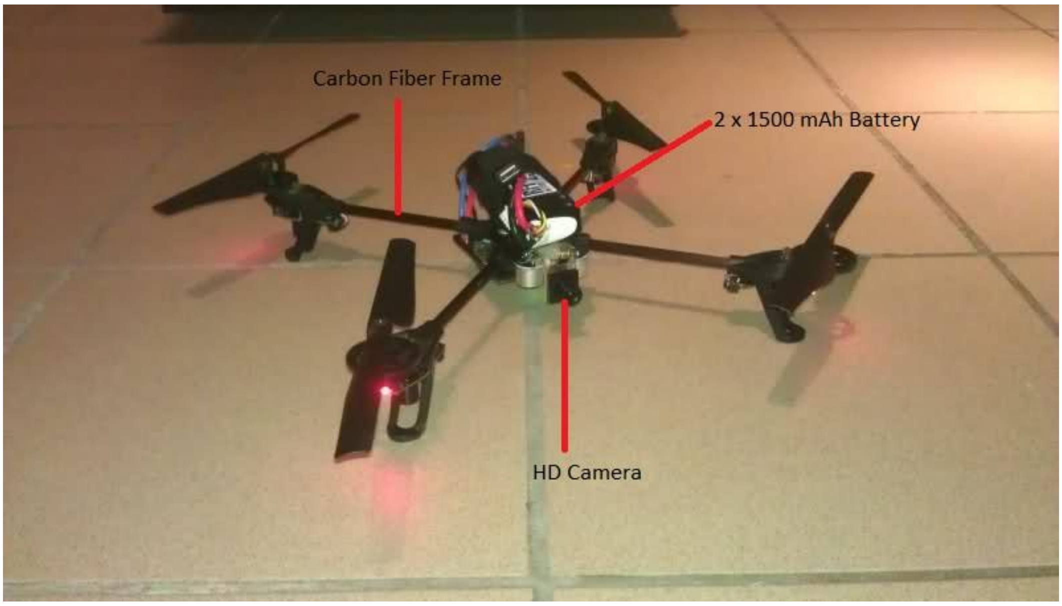


Figure 2 Quadcopter isomeric view.

Altitude detection and hold is also possible by using ultrasound sensors on the quadcopter. And the quadcopter also has barometric pressure sensor on-board provides unique stability that will automatically correct and maintain a still position in the air regardless of altitude and wind up to 15 m/h.

Figure 3 Quadcopter inverted view.

The following section is dedicated to describe the system application components.

A. System Overview

The main modules of our system are an object tracker and an Image Based Visual Servoing (IBVS) controller. As shown on Fig. 4, the drone is commanded by the controller at 15-25 Hz calculating the drone reference commands based on the bounding box provided by the object tracker. The quadcopter is operated using the flight mode when the object is tracked properly and it will be hovering otherwise. The software sets the drone to hovering mode when the tracker losses tracking for 200 ms or more. The following is a brief description of each of the modules:

1) Object tracker: our software is currently using a C++ open source implementation of the OpenTLD tracker. This tracker can robustly track objects on the drone's video stream. A great advantage of object trackers with learning capaibility is that they do not require any previous knowledge of the tracked object. It provides a bounding box (location, height and width) around the tracked object along with a confidence ratio.
2) IBVS controller: the controller closes four feedback loops based on image features, which are the bound-ing box location and size, at 15-25 Hz. The references to the controller are desired location of the centroid of the bounding

box in the image, and the size of bounding box. The resulting behavior of the system is that the drone will turn to look to the target and approximately control its relative position with regards to the target.

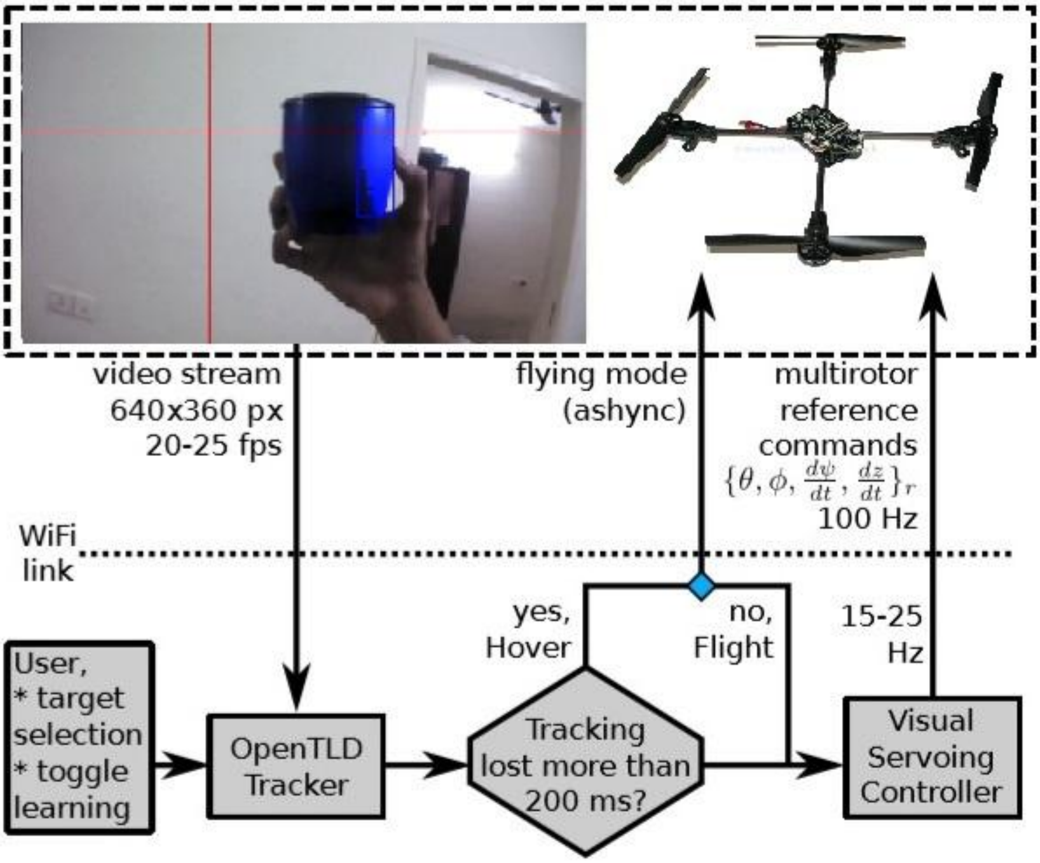


Fig. 4. System overview, the quadcopter is commanded from a computer over a WiFi link. The main components of the system are: the drone, the image rectification stage, the object tracker (OpenTLD tracker) and the controller. The user only interacts with the system to set the target to be visually tracked and to toggle the model learning of the tracker, in order to attain improved performance handling occlusions.

As a result of the above mentioned system architecture, the sensor information required during the experiments is (see Fig. 5):

1) During successful object tracking: the built-in opera-tion of the drone requires, at all times, to use the IMU and the ultrasound altitude sensor. Additionally, our off-board software uses only the front camera image to control the vehicle. Note that the optical flow based speed estimation is not used, either by the IBVS controller or by the quadcopter itself, during this operation mode.

2) Whenever the object tracking is lost or when the object is out of the image frame: the quadcopter is automatically commanded to enter hovering mode. As a result the optical flow speed estimation, in addition to the previous sensors, is internally used to stabilize the vehicle.

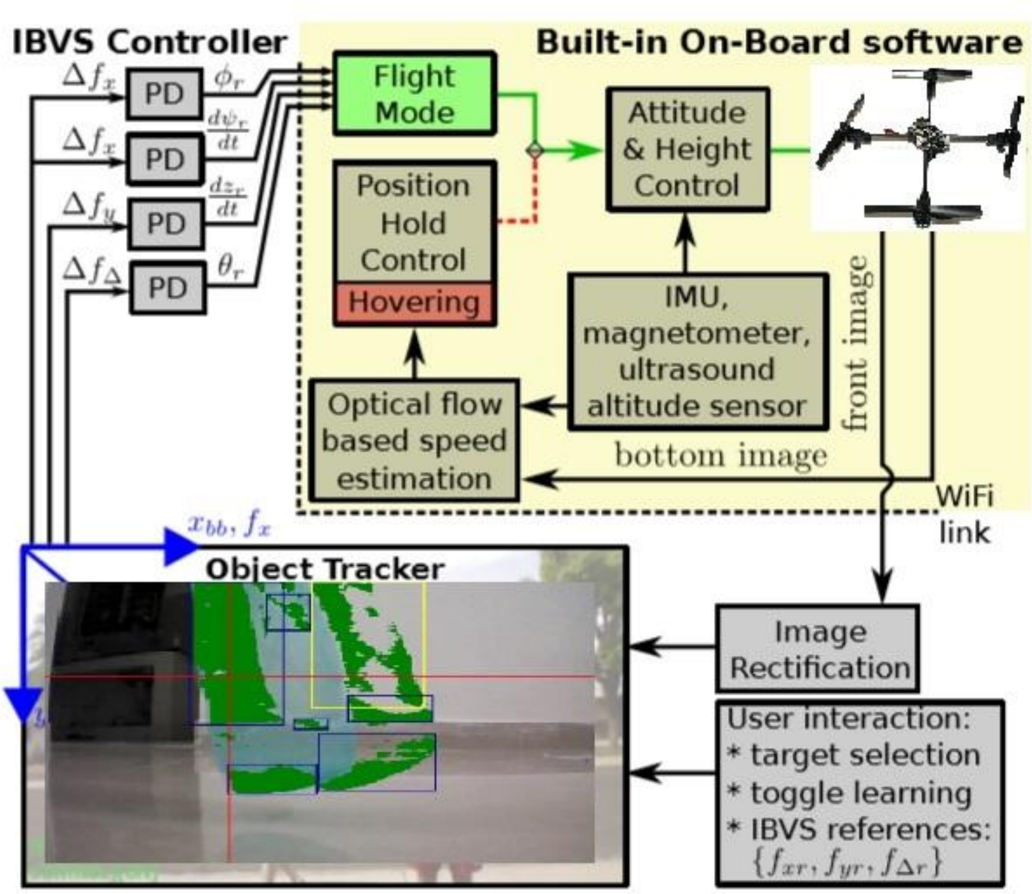


Fig. 5. Diagram of the Image Based Visual Servoing (IBVS) Controller. Since the tracker is working properly at this moment, the drone is operating under the flight mode and following the drone reference commands that the off-board computer is sending via WiFi. During flight mode, the optical flow speed estimation is unused. The figure shows the image features utilized by the controller, which are: ff$_x$; f$_y$ 2 [0; 1]g related to the centroid position and ff > 0g to the size of the bounding box.

B. Image Based Visual Servoing (IBVS) Controller

The user interacts with the system only to: take off, land, start the controller, change the IBVS controller references, select the targets to be tracked and to toggle, on and off, the learning feature of the tracker. As shown, the feedback measurements and the references used by the controller are directly related to the target's bounding box on the image plane. Thus, the controller, as implemented during the current experimental work is purely a Visual Servoing controller. As depicted on Fig. 5, the drone reference commands calculated by the controller are only taken into account when the drone is operated on “Flight Mode”.

The variables, measured in pixels, specify the estimate of the target’s bounding box as returned by the object tracker: horizontal x_{bb} and vertical y_{bb} location of its upper-left corner, and its width w_{bb} and height h_{bb}. Additionally the size constants of the image in pixels are: width w_{im} = 640 px, and height h_{im} = 360 px. The image features that are provided as feedback to the controller are calculated as follows, see Eq. 1 and Fig. 5, where x_{tm} is the frontal distance from drone to target:

$$f_x = \frac{x_{bb} + (w_{bb}/2)}{w_{im}}$$

$$f_y = \frac{y_{bb} + (h_{bb}/2)}{h_{im}}$$

$$f_\Delta = \sqrt{\frac{w_{im} \cdot h_{im}}{w_{bb} \cdot h_{bb}}} \mathrel{\underset{\sim}{\propto}} x_{tm} \quad \ldots\ldots \qquad \textbf{Eq. (1)}$$

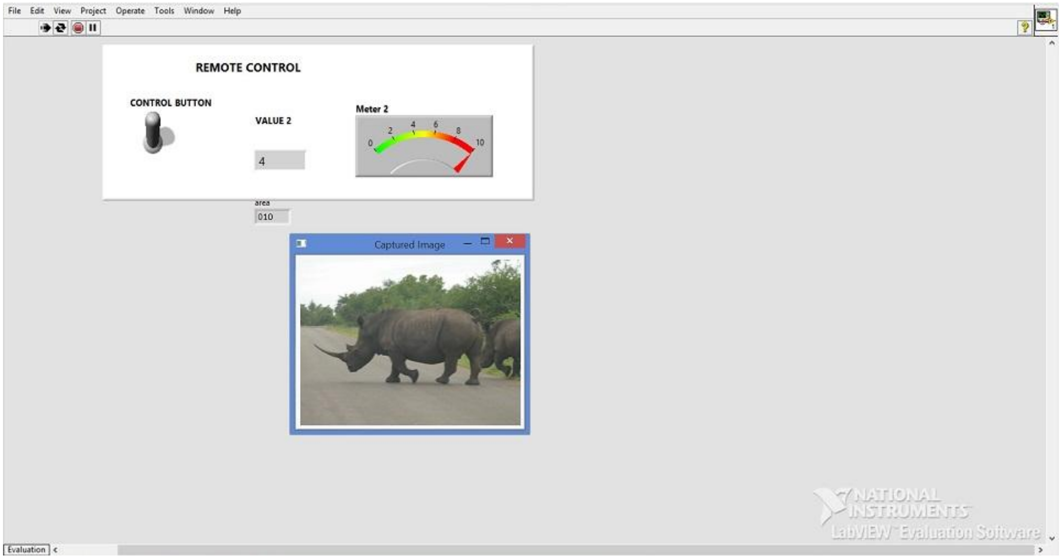
Note that the image feature f is approximately proportional to x_{tm}, the frontal distance from drone to target, which results in simpler and better performance on Visual Servoing controllers.

The behavior of the controller is successful, but the con-troller’s behavior is affected by the following factors:

- The controller is tuned to follow targets of surface size A_{exp} = 40 30 cm, at an expected distance of d_{exp} = 3 m.
- Multirotor’s degrees of freedom are not dynamically coupled, but in our system they are coupled by the controller architecture. The main couplings are the following:
- Pitch reference commands intended to control the distance to the target will cause the altitude controller to react unnecessarily.
- Yaw speed and roll reference commands cause similar movements on the horizontal centroid coordinate, f_x. Also, the dynamics of f_x are dominated by the yaw command. The effect on the system is that the PD controller that generates the roll commands is mainly stabilizing the platform laterally, but its action is not enough to counteract moderate winds.
- Due to the fact that the quadcopter’s frontal camera is fixed to the vehicle’s body, the yaw IBVS PD controller has to be strong enough to prevent the target of moving out of the image frame. A pan-tilt camera would allow to avoid this situation.

C. Area Measurement Using MSVS and LabVIEW

The user can measure the object area or land area approximately by implementing a Microsoft Visual Studio video cum image analysis programming in LabVIEW software. If the user desired to measure the object area then the video of the object is grabbed from primary front camera, for measuring land area then the video of the land is grabbed from secondary bottom camera and finally the grabbed video is feed inside the LabVIEW software for area analysis.



VALUE 2: 4

area: 010

Fig. 6. LabVIEW analysis of video for determination of area.

Fig. 6. Shows that a front camera captured video is taken for analysis to determine the area of an object by considering it by frame to frame analysis.

Iv. CONCLUSION

In this paper, a visual based object tracking and following system is presented. Our flying robot is able to follow of static and moving human targets, without any dependence on GPS signals, using a recently developed visual tracking and target model learning algorithm. The system does not require the targets to be marked, and no prior knowledge about the targets is required. Our system has been able to perform Visual Servoing task on targets of varying size, from a quarter to more than ten times the tunned target size, and at varying distances from 1-2 m to 10-15 m of distance from the target. It has also achieved person following at up to 1.5 m/s of speed.

Our system has been tested for person following tasks being able to handle occlusion by trees or other people. The computations are performed in an off-board computer that commands the vehicle from a WiFi link. Safety is assured even when the wire-less connection is suddenly degraded by using a multirotor platform that can attain on-board autonomous hovering using floor optical flow. The main contribution of the paper is to demonstrate that Visual Servoing on a great variety of targets including person following with occlusions handling, on an unstructured suburban area, and without dependence on GPS signals is feasible by a current low-cost but reliable UAV robotic platform.

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