A Review on Unmanned Aerial Vehicle for High Altitude Visual Inspection

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ABSTRACT

The Unmanned Aerial Vehicle (UAV) UAV is an operation aircraft with no pilot on board. Basically, UAV operates more flexible, and observable compared to ground approaches or other aerial methods which is airplanes and satellites for high altitude visual inspection purposed. This paper provides a review by studying significant research works on unmanned aerial vehicle for high altitude visual inspection. In particular, the working principle of UAV, related works on the UAV system for visual inspection using quadcopter and related works on the quadcopter performance are briefly described in this paper. Further research based on reviewed works will be conducted to improve previous experimental work.

Keywords: unmanned aerial vehicle, high altitude, visual inspection

1. Introduction

Visual inspection (VI) is a method of quality control assessment. VI, frequently used in facility maintenance, means the inspection of equipment and structures using either or all of them raw human senses. In conventional method, VI has been widely applied, is the most notable method for the surface detection. According to the traditional VI approach for surface inspection, it has inevitable drawbacks, such as limited detection range, high cost, and viewing angles are limited, especially for mountainous areas or dense areas. Conventional method of VI must be an efficient but still it can be questionable on business perspective, safety and health perspective, efficiency in co-ordination, cost impact and time effectiveness [1].

The Unmanned Aerial Vehicle (UAV) operates more flexible, and observable compared to ground approaches or other aerial methods which is airplanes and satellites for high altitude visual inspection purposed. In fact, the reduced size, weight and requirements for this aerial vehicle, together with the reduced cost of the visual inspection platform. UAV is an operation aircraft with no pilot on board. It is usually having two ways of operating; either remotely controlled with commands or controlled by computer with autonomously [2]. For the small UAVs have different advantages over their counterparts in terms of relatively low platform cost, ability to perform autonomous flight operations from take-off to landing and also to fly closer to the ground with no risk for a manned crew. Because of that, small UAVs are subject to significant payload restrictions compared to the larger aircraft. Pre-program flight plans can be delivered and automatically controlled on board, which means that small UAVs can be flown with greater precision and less workload than Manned Aerial Vehicle (MAV) aircrafts [3].

2. Principle of Unmanned Aerial Vehicle (UAV)

The Unmanned Aerial Vehicle System (UAVS) has two parts, the UAV itself and the control system. The UAV are control by remote Ground Control Systems (GSC) and also equipped with sensors and navigational systems. The rest of the body is full of drone technology systems since there is no space required to accommodate humans. The engineering materials used to build the drone are highly complex composites designed to absorb vibration, which decrease the sound produced. These materials are very light weight.

The working principle of the UAVS is shown in Figure 1. During take-off and flight, the UAV is autonomously controlled by the Flight controller and its GPS/IMU components. The UAV follows pre-defined flight paths computed by the flight-planning software. After completing the flight plan, the UAV returns to the starting point (Return to Launch-RTL). The system also features a half-autonomous mode, these called assisted flying mode. In this mode, the pilot is permanently supported by the autopilot software during UAV control. Height loss while flying turns or destabilization owing to wind is corrected automatically. This flying mode enables the pilot to safely steer and land the plane while confining the navigation area to a predefined range. This is especially useful for difficult terrain where fully autonomous landing may not be possible [4].

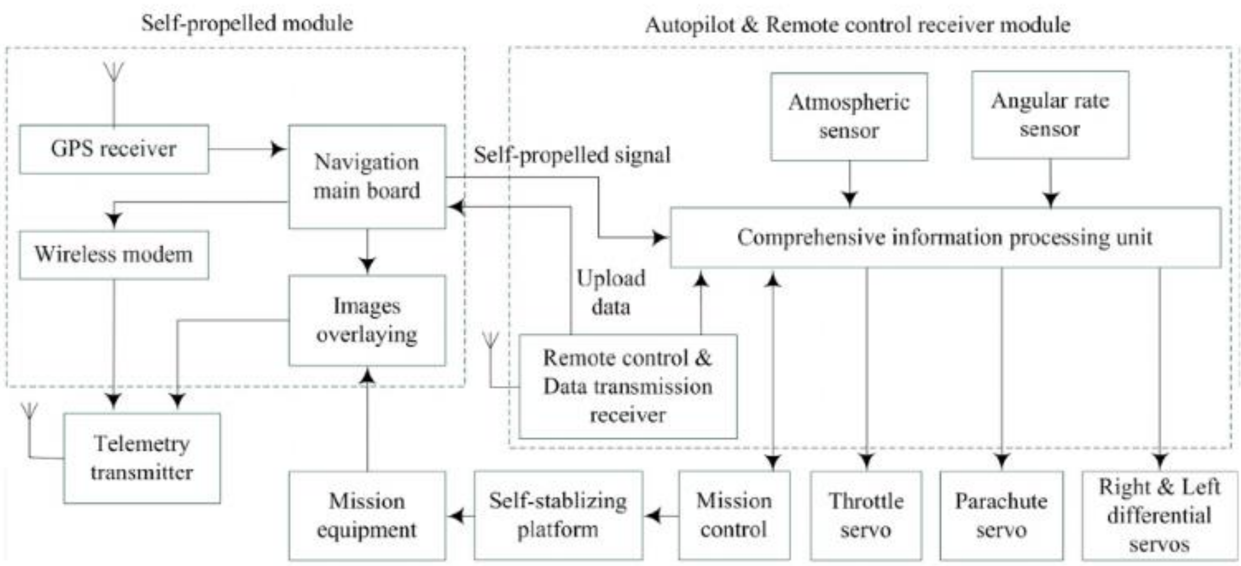

Figure 1. Working principle of the UAVs [4]

From the working principle of UAV, there are two different kinds of UAV which are multi-rotor (Quadcopter) and fixed wings. As a result, the performances and applications that these two UAVs are applied are different. The fixed wing UAV is similar to modern airplanes. It is larger in size and can fly at high altitude with very fast speed. For aerial surveillance application, it needs high resolution camera because the image can only be taken at high places. Besides that, the Quadcopter UAV is equipped with brushless rotors. Different from fixed wing UAV, multi-rotor can fly with slow speed but still maintain stable.

According to OSHA, sending inspectors up towers or on top of roofs for visual inspection contributes to falls and leading cause of death. They may also contact with toxic chemicals or emissions, moving machinery, and high-voltage equipment. Besides that, Helicopters can be a fast way to inspect from high altitude, but they pose a certain amount of risk as well. Today, the UAV are playing an increasingly important role in visual inspection and improving the reliability of the water, energy, and transportation systems [5].

Other than that, the hovering capabilities of Quadcopter UAV may be a good alternative, which allowing more accurate inspection procedures and extensive data collection of visual inspection. The conventional visual inspection processes performed can typically take up to one day, whereas UAV could significantly reduce the inspection time. The use of a reliable automatic visual inspection procedure with a UAV could substantially lower the incidence of omissions [6].

3. UAV Application

An unmanned aerial vehicle (UAV) is an aircraft without a human pilot on board. UAVs are a component of an unmanned aircraft system (UAS) which include a ground-based controller, and a system of communications between the two. The flight of UAV may operate with various degrees of autonomy, either under remote control by a human operator or autonomously by on board computers.

Due to the physical size and power, also differ in terms of capability and simplicity of operation, the UAV was included in variety of different platforms. These factors affect the capacity to transport load, speed, elevation and distance, which determine the different applications that each UAV can make. Small UAVs have different advantages over their counterparts in terms of relatively low platform cost, ability to perform autonomous flight operations from take-off to landing and also to fly closer to the ground with no risk for a manned crew. Because of that, small UAVs are subject to significant payload restrictions compared to the larger aircraft. Pre-program flight plans can be delivered and automatically controlled on board, which means that small UAVs can be flown with greater precision and less workload than MAVs aircrafts.

As mentioned, UAV is aerodynamic vehicle that operates without a carrier on board. It typically consists of structures, aerodynamic elements, driving mechanisms and control systems. For Quadcopter UAV equipment, from a body with a few small electric motors, propellers, which largely provide thrust in a vertical direction. Besides that, instead for fixed wing UAV, it has a fixed lift generating surface with the motor to generate thrust for the horizontal direction, as shown in Figure 2.1. The development of UAVs has been driven in the military. The development began as early as 1917, with the advent of Kettering Aerial Torpedo and Sporf-Curtis Torpedo Aerial, and today, with the emergence of UAVs such as Predators Global Hawk [7].

Figure 2. Fixed Wing (left) and Quadcopter (right)

UAVs are also used in applications including for TV and cinema, atmospheric and meteorological research, and for agricultural purposes. In 2006, it is anticipated that future applications will include a variety of surveillance and monitoring tasks, as well as telecommunications and atmospheric sampling [8].

4. Related Works on the UAV System for Visual Inspection using Quadcopter

4.1 Quality Assessment of Unmanned Aerial Vehicle (UAV) Based Visual Inspection [9]

This work discusses the application of Unmanned Aerial Vehicles (UAV) for damage detection and visual inspection on civil structures using videos and photos taken using such airborne vehicles. From the work, it has been found that wind speed and direction have fluctuated the vehicle's movement and affects the quality of the pictures and videos.

However, the damage detection on structure still can be identified. This paper also discusses the characteristics of such aviation systems and the factors that influence their movement and the quality of the photos they produce [9].

4.2 A UAV-Based Visual Inspection Method for Rail Surface Defects [10]

This article discussed a visual inspection approach based on unmanned aerial vehicle (UAV) images, compare to human inspection and rail vehicle inspection before this for the detection of rail surface defects. There are many shortcomings from human inspection and rail vehicle inspection, such as low efficiency, high cost, and so on. Two visual comparisons between old method and UAV experiments were carried out to demonstrate the efficiency of the proposed methods. From the results, it has been reported that the quantitative comparison presented efficient performance and proposed approach feasible to be used for the detection of rail surface defections [10].

4.3 New Robot for Power Line Inspection [11]

This article focused on the main achievements in the field of robotic power line inspections. It's used a different solution in climbing and flying robots are critically assessed in the paper and a new concept for robot-assisted power line inspection combining both flying and climbing principles is researched. For a robot-assisted inspection that can be carried out faster, cheaper and more reliable, improving the long-term stability of the power supply. The inspection of the power industry workers would also be improved. A new type of robot that is both climbing and flying is proposed to include the advantages of both and the solution is then critically assessed and related to other robots in terms of design, construction, inspection quality, autonomy and universality. The proposed solution would combine a helicopter that could fly over obstacles and a special drive mechanism for traveling on the conductor up to an obstacle [11].

4.4 Power Line Inspection - An UAV Concept [12]

A different robot was proposed in 'Power Line Inspection - An UAV Concept the robot' as pictured in Figure 3, would hover over the power line using a ducted fan configuration. The ducted fan configuration is efficient at hover due to the low speeds expected during inspection and the cowl gives protection from the propellers if a fault condition causes it to fall to the ground. The robot proposed in would use no fuel and have a minimal battery as it would pick up a charge using a mechanism like an active pantograph. The limited battery makes the vehicle light and effectively tethers it to the transmission line, only providing power for maneuvering over small obstacles in the line. It does have the drawback of only being able to be used on energized lines. A dynamic model of the ducted fan unit has been derived and programmed onto the Air Vehicle Simulator facility at CSIRO in Brisbane [12].

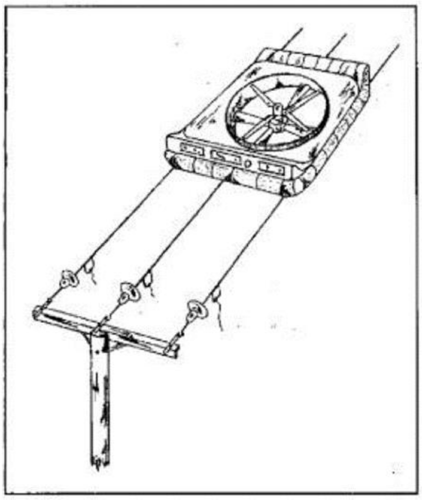

Figure 3. Artist's illustration of the concept [12]

4.5 Power Line Inspection with a Flying Robot [13]

The Power Line Inspection with a Flying Robot article and researched the use of unmanned flying robots in power line inspection. The paper researched the use of two Unmanned Autonomous Helicopters, (UAH) to inspect the power line corridor including power lines, poles, towers and vegetation which is common inspection work in the power industry. The research by used two UAH to design a flying robot called Smart Copter for inspecting power line corridors. Where previous research had focused on autonomous control of UAH and vision guidance, this paper focused on besides flight control, the inspection system design. The Smart Copter in was designed to fly at low height; hover for careful inspection and did not require a take-off or landing area. The inspection control system consisted of a thermal and a visual camera. The results of the experiments in concluded the Smart Copter can safely fly 50 meters away from power lines. At that distance Smart Copter can use the digital camera and thermal camera to inspect power lines. The thermal inspection did not meet the expected requirement, but there as a way to improve it. The Smart Copter could be used for other applications in the power industry and extended or modified for other infrastructure including railways, pipelines and cellular phone towers [13].

4.6 The Autonomous Scale Model Surveillance Aircraft [14]

This research has been conducted for the UAV design for surveillance purposes. Comparison of UAV technology used to gain insight into technological development. For example, the author used a Motorola HC12 processor to control the airframe and had to program the controls for the flight and use dead reckoning for the autonomy. Technology in 2013 has increased so that now a small lightweight and affordable autopilot are available with global positioning systems, compass and gyro in one small lightweight package. They used open-source programming and basic programs are available on the internet [14].

4.7 Advanced Arial Inspection and Asset Management of Electricity Towers [15]

This research was discussed methods of foot patrols, climbing inspections and helicopter inspections. Each method had advantages and disadvantages. The helicopter inspections offered the greatest area for improvement from inspection and picture acquisition. This was proven from produce superior results to picture and video for this application. The conclusions of were those inspections of electricity distribution towers from a helicopter using high resolution imaging can be combined with condition assessment to provide a complete and unique solution to tower asset management. The technique has been used United Kingdom and Australia [15].

5. Related Works on the Quadcopter Performance

5.1 In Intelligent Fuzzy Controller of Quadcopter [16]

An intelligent system on fuzzy control is designed and implemented to control a Quadcopter. A quadrotor has six degrees of freedom regarding the position: height, horizontal and vertical motions; and the other three are related to the orientation pitch, roll and yaw. The outputs are the power of each of the four rotors that is necessary to reach the specifications. Simulation results prove the efficiency of this intelligent control strategy is acceptable. Figure 2.3 represents the proposed fuzzy control diagram in [16].

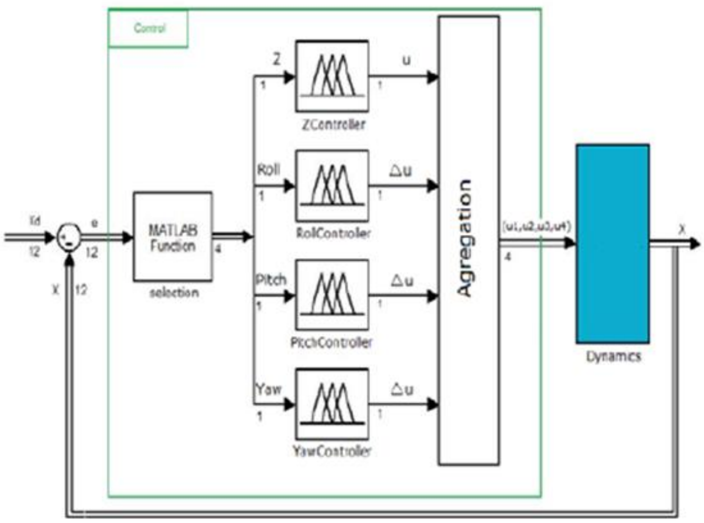

Figure 4. Fuzzy Control Diagram

5.2 Design and Analysis of Quadcopter Classical Controller [17]

The simulation of the controller design was developed in MATLAB/Simulink. In order to design the attitude controller, the transfer function of the brushless DC motors which are responsible of the Quadcopter motion is obtained using system identification techniques. A complete test experiment is achieved goal. The block diagram for closed loop system of Quadcopter proposed in this study is given in Figure 5 [17].

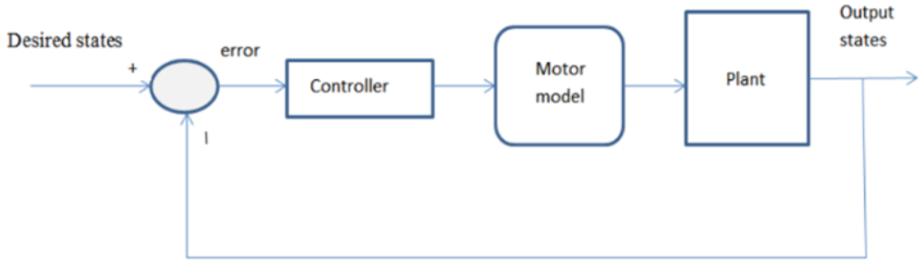

Figure 5. Block diagram of closed loop system

6. Discussion

High-altitude visual inspection is one of the most difficult tasks for the Non-Destructive Testing (NDT) Inspectors. This is because they are exposed to many hazards, when working at height and facing some limitation that always involve in conventional visual inspection at high altitudes. One of the limits is using sky lift, this is because it cannot go higher than the design height and difficult to move from one place to another. Other than that, the cost of using man aerial vehicle (MAV) i.e. helicopter, will be more expensive due to rent and fuel cost. During visual inspection NDT inspectors usually tend to do mistake and overlook around the inspection area. In terms of safety and health, they will be directly exposed to hazard a working area such as chemical, radiation and biologically. Although NDT inspectors have experience and expertise, time efficiency is difficult to achieved due to limited information and extensive of area inspection. It is therefore, reviewed works above are significant to be discussed in order to seek an idea how Quadcopter UAV can be considered for high altitude visual inspection purpose. From the review, it can be noted that the hovering stability assurance of the proposed UAV has been successfully attained by using a quadcopter (4-propellers) approach. Using Quadcopter, it is forecasted that simple UAV design can be developed, but still able to provide good UAV functions, and also cheaper in costs for the installation, operation and maintenance tasks. However, to minimize the risks associated with UAV flight/maneuver, appropriate software needs to be selected, to enable UAV can be controlled more dynamically for the pre-flight mission planner, in-flight monitoring, and post-flight log file analysis.

7. Conclusion

In this paper, relevant works that have been carried out regarding the unmanned aerial vehicle (UAV) for high altitude visual inspection system have been presented. The principle works of UAV, the relevant works on the UAV system for visual inspection using Quadcopter and its performance issue have been demonstrated. It is envisaged that this quick review work could give a motivation towards the study on the designing and developing the UAV for visual inspection using quadcopter in the future.

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