Aerial Grasping and Load Transportation Using Multirotor Helicopters
Towards Moving Long-size Payload

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In this paper, we propose a solution for grasping and moving long-size payload such as pipes or wood using a multirotor helicopter. In order to perform this task, a couple of grippers were mounted under the helicopter for a better grasping and safe transportation. Some experiments performed show that the helicopter can safely grasp and move the payload to another place. By means of an on-board camera, the helicopter can provide visual information to the user at the moment of the aerial manipulation using either a First Personal View video goggles or a small monitor. The complete system is commanded using a single radio control.

***Key Words*:** Aerial manipulation, long-size payload, multirotor helicopter.

1. Introduction

Multirotor aerial vehicles have been the focus of attention in the last decade; this is largely because of their mechanical simplicity compared with the traditional helicopter (main-rotor tail-rotor), low cost and easy maintenance. The quadrotor helicopter has been used widely around the world in a variety of researches, these include different linear and nonlinear control strategies [1] [2] [3] [4] [5], vision based navigation [6] and even swarms [7]. Recently, a new topic has attracted the attention of the research community around the world; this topic is called "Aerial Manipulation" and it represents a new set of problems and challengers. Since previous research was focused only in tasks without physical interaction with the environment, Aerial Manipulation represents the next step in the evolution of such multirotor systems because of the diversity of possible applications. The use of this new type of aerial robots ranging from material transportation in hostile environments, assembly structures, and industrial maintenance to washing the windows of a building, or even transporting supplies in a disaster area or in inaccessible places.

In order to provide a manipulator or a simple gripper to interact with the environment, several contributions have been done. A UAV (Unmanned Aerial Vehicle) endowed with a manipulator is used to control the contact force on the end effector in a normal direction to a vertical surface [8], autonomous helicopter equipped with a robotic arm for aerial manipulation [9], stability analysis during aerial grasping task [10], modeling and mechanical design of a Delta Robotic manipulator for a ducted-fan UAV [11], modeling and control of a flying robot for contact inspection [12] are some representative examples of such research.

Among the diversity of activities a multirotor may perform by means of physical contact, moving a payload from one place to another represent one of the most basic activities. However, this task requires a good grasping process and keeps the payload as close as possible of the center of gravity to maintain the stability of the aircraft. In this research, we are focus on both, grasping and transporting a payload, specially, long-size payload. This is because there are places in which the access is difficult as a result of a natural disaster or because of the necessity to delivery construction material in hazardous environments. As a first approach, we are interested in testing a commercial hexarotor helicopter, typically used for aerial video and photography, to find out whether or not it can safely deal with the process of grasping and moving long-size payload. In addition, the use of two grippers to perform the grasping task is also introduced.

2. Description of the System

Nowadays, among the great variety of multirotors available, the hexarotor helicopter has emerged as an elegant and reliable option to perform aerial manipulation. It is between the quadrotor and the octarotor and compared with the former, hexarotors can carry heavier payload and the energy consumption is less than the latter.

2.1 DJI S800 EVO

The hexarotor helicopter used in these experiments was the DJI S800 EVO from DJI Company [13]. This helicopter is used for professional aerial video and photography; the main characteristics of the frame and the payload capacity are shown in Table 1. The flight controller used for these experiments is the DJI A2 [14]; the complete set is composed by the main controller, a high sensitive Inertial Measurement Unit (IMU), a GPS-COMPASS, a power management unit and a LED indicator. Among the most important features are that the flight controller can be bound with the Futaba S-Bus, S-Bus2, and DSM2 using its own built-in receiver. It also can support external receivers, Fig. 1 shows the connection between the different elements. The reader is invited to consult the DJI references at the end of this paper to go deeper into the characteristics of this flight controller.

Table 1: Specifications of DJI S800 EVO

Frame weight	4.02 kg
Flight time	16-22 min with 1.2 kg payload and 6S 10000 mAh battery
Maximum payload capacity	3 Kg(with 6S 5000 mAh battery)

In order to control the hexarotor, a Futaba aircraft radio control 14SG was used [15]. This radio transmitter has 14 channels and can be bound with the DJI A2 without the necessity to connect a receiver. Because the flight controller uses a GPS signal, the user can keep the hovering position (x, y, z) of the DJI S800 EVO simply by moving both Futaba stick controllers to the middle position. It is worth mentioning that this feature is only available provided that there are six or more satellites during the flying time.

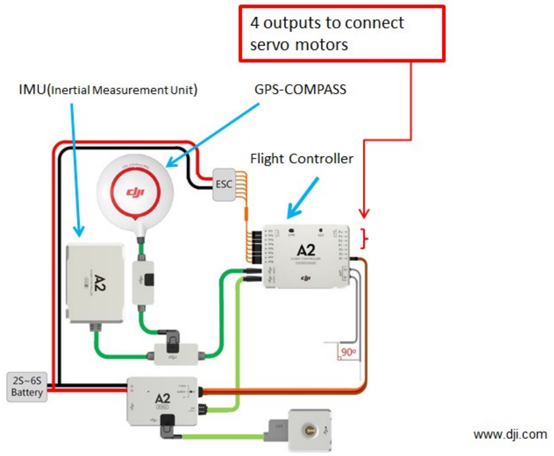


Fig. 1 DJI flight controller [14]

2.2 System Integration

The DJI A2 flight controller provides four independent and configurable PWM output channels (from F_1 to F_4). Three of these channels, F_4, F_3 and F_1 were used to send the control signal to the grippers, to control the angle of the on-board camera and to control the landing gear respectively. On the other hand, the hexarotor needs four input signals from the radio controller to place it in a tridimensional space (x, y, z), this signals are pitch θ, roll ϕ, yaw ψ and throttle T. It also needs three input signals G, η and L to close and open the grippers, to move the gimbal camera and to fold the landing gear respectively. Fig. 2 shows the block connection between the different components of the system.

The two parallel grippers used in this work are placed below the helicopter; they provide the necessary force to grasp the long-size payload and also help to maintain it horizontally during the process of transportation. The complete system is shown in Fig. 3.

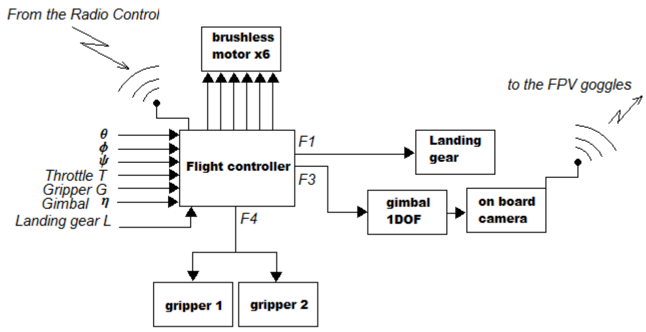


Fig. 2 Block diagram with the connection of the different components mounted on the hexarotor helicopter

3. Testing the Hexarotor Helicopter

Basically, the experiment consisted of flying the helicopter from a safe place to the target, in this case a PVC pipe, which has to be grasped and moved to another place. The speed of the wind was around 5km/h and the battery was fully charged, Fig 4 shows a comparison between the dimensions of the hexarotor and the pipe. Fig. 5(a) shows the hexarotor flying to the target, Fig. 5(b) shows the target localization, Fig. 5(c) shows the moment of grasping the pipe, Fig. 5(d) shows a hovering pause to recover the stability after the grasping process, Fig. 5(e) shows the aircraft flying to another place and finally, Fig. 5(f) shows when the hexarotor is gaining altitude and heading to the final position. Table 2 shows the main characteristics of the payload and the energy source.

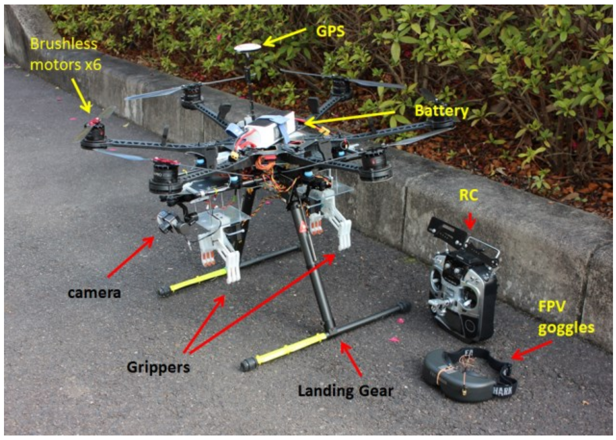


Fig. 3 System integrated

Table 2: Payload and battery characteristics

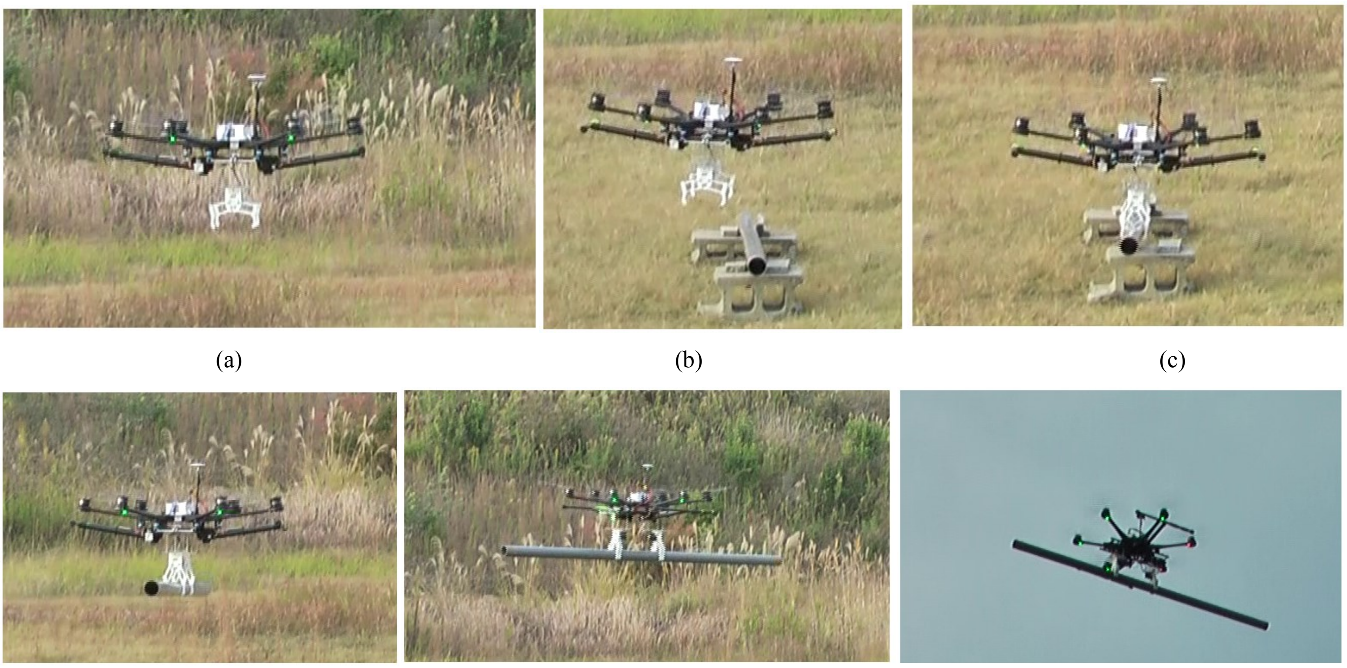
Length of the payload	2m
Weight of the payload	1030g
Battery	6S (5000 mAh)

Fig. 4 DJI S800 and the payload to be moved

4. Conclusions and future work

Grasping and transporting a payload may lead to undesirable behavior in the aircraft. This means, the stability of the helicopter might be affected at the moment of detaching the load from the ground causing that it starts oscillating and consequently, lose the control and sometimes crash. Moreover, if the payload is not properly grasped, it may fall down during the process of transportation causing serious damage in people or in the payload itself.

For potential applications, aerial manipulation using multirotor helicopters might be an alternative for all those places with difficult access that require delivery construction material or even in emergency situations. Although the helicopter used in this work could successfully grasp and move a pipe, the performance might be affected by the external factors such as wind or rain as well as the center of gravity of the load. Currently, we are working on solve this last problem of grasping a load around the center of gravity. This task causes a negative effect in the stability of the multirotor causing that it starts swinging and some times, depending of the weight of the payload, lose the control.



(a) (b) (c)

(d) (e) (f)

Fig. 5 Process of grasping and transporting a PVC pipe. (a) Flying to the target, (b) target localization, (c) grasping the PVC pipe, (d) hovering pause to recover the stability, (e) preparing to fly to the destination, (f) heading to the final destination.

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