Small Sized Drone Fall Recover Mechanism Design

Tzu-Heng LIU\textsuperscript{1}, Fang-Lin CHAO\textsuperscript{1,*} and Jhen-Yuan LIOU\textsuperscript{1}

\textsuperscript{1}Department of Industrial Design, Chaoyang University of Technology, Taichung, 436, Taiwan, R.O.C.

*flin@cyut.edu.tw

Abstract: Drones uses four motors to rotate clockwise, counter-clockwise, or change in rotational speed to change its status of motion. The problem of Unmanned Aerial Vehicle turnover causes personal loses and harm local environment. Designs of devices that can let falling drones recover are discussed. The models attempt to change the orientation, so that the drone may be able to improve to the point where it can take off again. The design flow included looking for functional elements, using simplify model to estimate primary functional characteristics, and find the appropriate design parameters. For reducing the complexity, we adopted the simple rotate mechanism with rotating arms to change the fuselage angle and reduce the dependence on the extra-components. A rough model was built to verify structure, and then the concept drawing and prototype were constructed. We made the prototype through the integration of mechanical part and the electronic control circuit. The electronic control module that selected is Arduino-mini pro. Through the Bluetooth modules, user can start the rebound mechanism by the motor control signal. Protections frames are added around each propeller to improve the body rotate problem. Limited by current size of Arduino module, motor and rebound mechanism make the main chassis more massive than the commercial product. However, built-in sensor and circuit miniaturization will improve it in future.

1. Introduction
Drones have increasingly broad applications. It uses four motors to rotate clockwise, counter-clockwise, or change in rotational speed to change its status of motion. It can demonstrate styles of flying such as (1) perpendicular motion, (2) pitch motion, (3) roll motion, (4) yaw motion, (5) front and back motion, and (6) Sideways move \cite{1}. The problem of drones/ Unmanned Aerial Vehicle (UAV) falling causes personal loses and disturbing local environment \cite{2}. One may often hear of incidents where drones used for aerial photography and filming or other purposes lose control and fall, thus endangering public safety.

Currently some patented applications already exist that functions like the active safety systems of cars, which intervene once the driver's actions endanger safety: For instance, Taiwan Patent no. M518111 \cite{3} (active obstacle avoidance system of drone) is similar to a car's active safety system that changes the driver's manner and amount of control at times. Processing unit features receive inputs from multiple distance sensors, decode control signals, and simultaneously read the measurement results from the sensor. Using this information, it can then use the rules for obstacle avoidance and modify the controls at appropriate times.

Drones have also been used in field data collection, in Patent No. M510456 \cite{4}, a drone is designed to collect water samples. It uses GPS navigation or remote control to fly to a destination, hover above
the water surface, and uses weight and buoyancy to change the angle and orientation of the automatic water-sampling cup, and proceed to collect water samples near a pollution source. During field data collection, the drone may be affected by the terrain or above ground objects, and fall and turn upside-down [4]. The propellers of the drone cannot freely rotate while accidentally falls. It is unable to recover from falling by itself. In US3273835A [5], a practical system for monitoring in-flight conditions aboard a target drone which will respond to power failures on the drone electrical system or to drone destruct signals. System ejects the instrument package and initiates a transmission of homing beacon signals to ensure the maintainability.

In this study, we design the mechanism that can let falling drones recover. The designs attempt to change the orientation so that the drone can back to the point where it can take off again. These compositions may help increase the probability of a drone involved in an accident to return.

2. Design approach
Drones use built-in micro-controllers to control the motors, thus changing their mode of locomotion. The flipping that occurs after a fall is related to jumping motion. UC Berkeley has designed a small robot that can leap into the air and then spring off a wall [6], or perform multiple vertical jumps in a row. Spring stored energy within long duration, later released in a short time. For reducing the complexity, we adopted the simple rotate mechanism which uses residual power.

2.1. Design process
The design flow shows in Figure 1; first look for related functional elements then simplify the functional characteristics of simplified model. Through the simulation, we can find the appropriate design parameters. A rough model was built to verify structure status, and then the concept drawing and prototype were constructed by designer.

![Figure 1. Design flowchart](image)

2.2. Rollover
Micro-UAVs usually have four blades, controlled by speed changes to ensure a stable posture. When performing the rollover, it is necessary to control the small support foot of the self-starting device to change the fuselage angle. The self-starting device shall be low weight so that the structure which attempts to change the body angle will not cause a significant increase in the total weight. For reducing complexity, the simple rotate mechanism was adopted with rotating arm to adjust the fuselage angle and reduce the dependence on the extra-components.
Firstly, the Working Model 2D has utilized to simulation different conditions of rotate mechanism given uniform mass distribution. When the fulcrum position moved to the center of gravity, the object does not move horizontally, and the main chassis can be reversed in short time (Figure 2). Refer to Figure 3 of qualitative observation; the length of the support shaft is increased to make sure that the rollover occurs. When the fulcrum position moves to the center of gravity, rollover also occurs earlier.

![Figure 2. The change of the shaft position on the flipping](image1)

![Figure 3. The change of shaft length on the flipping](image2)

In the real flying body, the mass distribution is not uniform; the main body chassis is much smaller than the top of the four rotating propellers. At this time, it is necessary to increase the length of the rotating rod. The total mass is 207g, diagonal distance between propellers is 27cm, and propeller radius is 7cm. After the experiment, the length of the rotate rod is chosen to be 20.6 cm.

3. Concept design

![Figure 4. Idea schematic drawing](image3)
3.1. Physically flip the drone.
Naturally, the center of gravity and center of the object will be the lowest position. A dome frame protector was installed to replace circular protectors. The dome frame protector enlarges the volume of drone with small additional weight. We move the Lithium battery to lower position to keep the gravity center of drone lower. Computer simulations were successful predict the rollover. The result of prototype test deviated with the prediction. Consequently, covering structure in outer edge of the fan was adopted.

We try to lift the center of gravity to flip the drone. According to the results of simulation and parameters test, we explored several design concepts through brainstorming. One of the ideas shown in Figure 4. Outside the bracket, there is a circuit ring made of carbon fiber to enhance the structural strength and reduce the weight. Figure 5 proposes to add a covered structure (#12) on the outer edge of the fan’s blade to prevent the possible damage [7] and surround matter into the blade rotation range. At the one end of the body chassis, there is a support shaft (#P1) with fulcrum near side of the body (#212) for turning over. The hoisting mechanism uses a remote signal (#S) to activate and control the servo motor (#22).

![Figure 5. Outer edge of the fan is added covering structure](image)

3.2. Prototyping
During prototyping step, designer need consider all the parts (chassis, motor, and controller) that obtained, and how to connect them to demonstrate major functions. The electronic control module that selected is Arduino-mini pro [8] with installation of Bluetooth module [9] and Servo motor (Figure 6). The user can start the rebound mechanism circuit by the signal from remote controller. There is a corresponding Bluetooth transmitter operate by 2.4G signal in remote controller. Limited by the size of Arduino module [10], motor and rebound mechanism makes the main chassis larger than a commercial product. However, during the mass production phase, the electronic control module can be customized to reduce the size of circuit board and chassis. For maintain the strength of overall structure, the main body was 3D printed with PLA material, but the four arms made of carbon pipes.
3.3. Evaluations

The servo-driven rebound lever turns the body back to the fly state. We verified the effect and possible pitfalls in the evaluation phase. The original drone (Figure 6) do not have protection frame around propeller blade. Sometimes the blade position causes it fails turnover correctly (Figure 7). Protection frames are added to each fan to fix this pitfall. The situation was significantly improved. We observed that almost every time the rebound angle is the same (Figure 8, 9). The protection frame around fan led to a drawback of additional weight. Lightweight materials and the frame structure which remove the unnecessary stuff need further investigation.

Figure 6. The servo-driven rebound lever: (left) structure, (right) Arduino board connections.

Figure 7. Propeller without protection ring: skew, cannot be successfully turned

Figure 8. Propeller with protection ring: can successfully stand up
4. Conclusions
The design process use prototype and simulation to verify design situations, designer can find the appropriate design parameters. The prototype constructed through integration of mechanical part and the remote control circuit through the Bluetooth linking channel. Protection frames were added around each propeller to improve the flip over and change the drone position to facilitate the take-off. Limited by current size of Arduino module, motor and rebound mechanism made the main chassis larger than a commercial product. However, we will improve this through built-in sensor and circuit miniaturization in future. Remote app interface enables user in knowing the control conditions. This feature reduces the number of attempts and increases the opportunities for successful practice.

References
[1] K. P. Valavanis, Ed. 2011 Special issue on unmanned aerial vehicles, J. Intell. Robot. Syst., vol. 61, pp 1–585
[2] David Cabecinhas, Roberto Naldi, 2016 Robust Landing and Sliding Maneuver Hybrid Controller for a Quadrotor Vehicle, IEEE Transactions On Control Systems Technology, 24, no. 2, pp 400-408
[3] Taiwan patent, M-518111, http://twpat-simple.tipo.gov.tw/tipotwoc/tipotwkm?!!FR^M518111
[4] Taiwan patent, M-510456, http://twpat-simple.tipo.gov.tw/tipotwoc/tipotwkm?!!FR^M510456
[5] US patent, US3273835A, https://patents.google.com/patent/US3273835A
[6] http://news.berkeley.edu/2016/12/06/wall-jumping-robot-is-most-vertically-agile-ever-built/
[7] Taiwan patent, I586414, http://twpat-simple.tipo.gov.tw/tipotwoc/tipotwkm?!!FR^I586414
[8] A. D’ Ausilio, 2011 Arduino: a low-cost multipurpose lab equipment, Behaviour Research Methods, vol. 44, Issue 2, pp 305-313
[9] Arduino shield list: http://shieldlist.org.
[10] A. Garrig, D. Marroqui, J. M. Blanes, R. Gutierrez, 2017 Designing Arduino electronic shields: experiences from secondary and university courses, IEEE Global Engineering Education Conference (EDUCON), Athens, Greece, pp 935-937