Aerial Maneuvering for UAV via Feedback Control System

Introduction

In the past year, legislation in California and its border states a significant amount of emphasis on the legality of owning and operating UAVs (Unmanned Aerial Vehicles). While the specifics about safety and privacy for the public are not agreed upon, the commercial and scientific benefits of such systems are widely accepted. However, because they have been illegal to use without permission from the government, little research has been done on the commercial applications of UAVs. My paper will attempt to create a feedback control system to control various aerial movements in a UAV. Because the discussion of an entire system to control the UAV would be too broad, I will limit my control system to the controlling the altitude component of the system, as well as touch on some other components such direction control and collision detection.

Relevance

In 2012, the Federal Aviation Administration Modernization and Reform act was signed into federal law, which states in Title III Subtitle B: "the Secretary of Transportation, in consultation with representatives of the aviation industry, Federal agencies that employ unmanned aircraft systems technology in the national airspace system, and the unmanned aircraft systems industry, shall develop a comprehensive plan to safely accelerate the integration of civil unmanned aircraft systems into the national airspace system." Operational and certification requirements for UAVs are to be established no later than December 31, 2015. On February 22, 2013, California Assembly members Gorell and Bradford were the first to introduce legislation that attempted to implement this plan. California bills AB1326 and AB1327 aimed to make the commercial and personal ownership of UAVs legal, as well as provide tax benefits to those that chose to invest in such progressive ventures.

Design Specifications

Movement

Figure 1 shows a initial mockup of the UAV created in Google Sketchup. The control system I designed is contains four duct fans placed in each corner of the rectangular craft. For simplicity, I have left key areas open in the diagram, such as the remaining walls of the cargo bay and the four air channels connecting the fans to the lateral ducts. The lateral and horizontal movement will be controlled completely by a series of channels inside the ducts that will push the air evenly through the exit vents. As you can see from the diagram, forcing the air downwards through the vents placed on the side rather than exiting directly beneath the cargo bay achieves thrust. This design exerts force in the optimal position to maintain balance while maximizing thrust. The exit vents on the side promote rotational and horizontal movement depending on how you force the air.

Parts

For this design, I chose four ducted fans (effectively a "quadcopter"/ducted fan hybrid) because it provides a maximum thrust to weight ratio while maintaining acceptable maneuverability. Maneuverability is highly dependent upon the rate at which your fan can adjust thrust (or rotations per minute), so the conciseness of the fan's control system is key to creating a craft that is agile. Furthermore, the VTOL (vertical takeoff or landing) design is essential to a successful package delivery application because of tightly packed residential and commercial buildings we find in society today. One of the major tasks of this project will be finding a ducted fan that maintains an acceptable balance of thrust and weight.

Dimensions

Because I have not tested any ducted fans for optimal performance and the lack of detailed online specifications, the dimensions for this project cannot be accurately projected. I can, however, make an educated guess and determine a reasonable range for these values. Through various articles and papers on quad motors thrust to weight ratio, I have determined that a reasonable that a safe value for thrust to weight ratio is 2:1. A commonly used EDF system (complete with motor) from Dr. Mad provides 2.35 kg of thrust while only adding 313 g to the craft per motor. If we were to add four of these to our system, we would have 8148 g of thrust remaining, or the ability for our payload to be 4074 g, or about 9 lb. for materials to make up the craft and the payload. I am anticipating the craft to be about 1.5 ft. x 1 ft. for the payload size, since we have relatively small fans. If one wanted to design a system to carry larger packages, more powerful fans must be used.

Control System

In this design, sensors would include accelerometers for pitch and yaw calculations, as well as GPS sensors for locational data. The controller would be a small microprocessor that makes calculations based on the sensor data and provides data to the plant on how to direct the fans. The plant will be comprised of the duct fan controls and well as the position on the ventilation shafts directing air either horizontally or vertically. Disturbance could come from quickly changing wind speeds, humidity, air pollution, and collisions. The output and desired variable would be dependent upon the state of the craft, which include Loading, Takeoff, Transport, Landing, and Delivery.

Conclusions

This design has been optimized for maneuverability and accessibility as defined by the problem itself. All of the parts included in this design are readily available for anyone to purchase and build, and thus the design of such a control system is very practical and beneficial. Such a product is not so impractical as a consumer might think at first glance, and might be available on the market much sooner than we had imagined just a few years ago.

Figure 1: UAV modeled in Google Sketchup

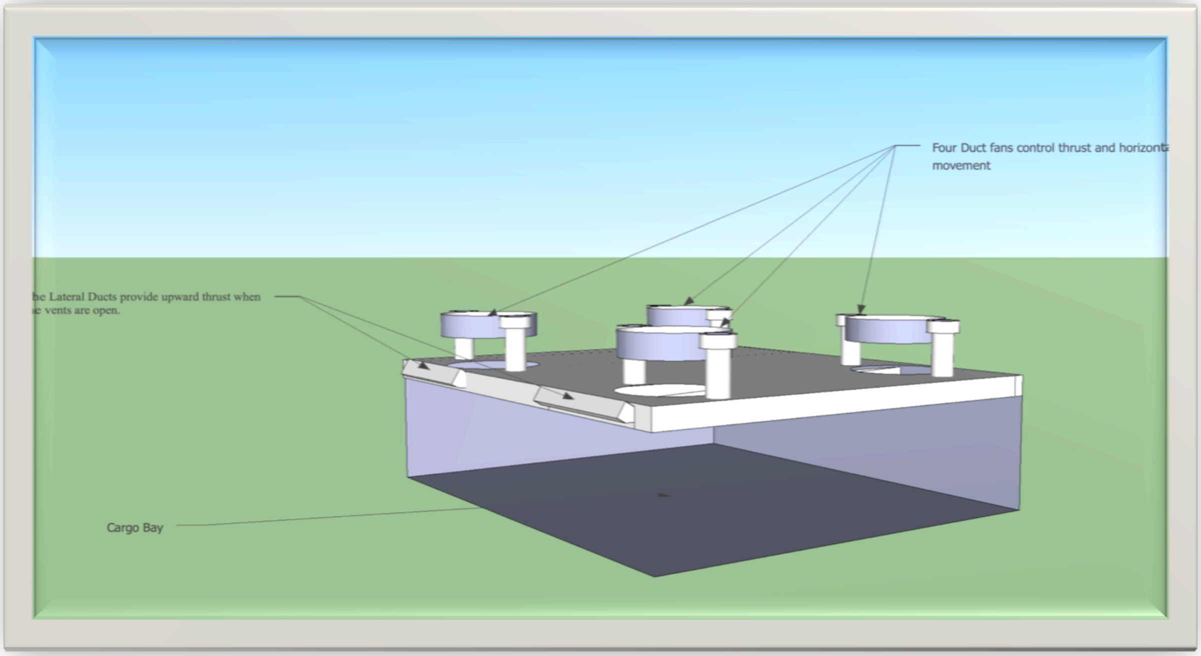

Figure 2: UAV modeled in Google Sketchup (Top)