Reconfigurable Unmanned Aerial Vehicles

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Abstract

Unmanned Aerial Vehicles (UAVs) have been developing dramatically due to wars and miniaturisation of technology, which has made the UAV industry a very lucrative business. Research organisations have been funded by various research committees or military groups to push UAV developments at a very fast pace. Although these UAVs are high in capability, they are limited to a single use application or mission.

This paper will analyse current UAV systems to determine how the use of a novel reconfigurable UAV could benefit the end user.

Keywords: *Unmanned, Reconfigurable, Morphing, Wing, Bio-mimicry.*

Introduction

Unmanned Vehicles are primarily used to conduct tasks which are too dangerous or impossible for humans to do. There are various types of unmanned systems used on the ground, underwater and air. Unmanned Aerial Vehicles (UAVs) are widely used to give the user an aerial view of a certain area such as in search and rescue, homeland security, environmental monitoring, aerial photography or even communications and broadcasting; however the biggest UAV user is the military who use them as the prime source of vital battlefield information in a process called Intelligence, Surveillance, Target Acquisition & Reconnaissance (ISTAR) [1].

The worldwide UAV market is very large and growing rapidly; according to a recent report from the Teal Group, US$4.4 bn was spent on nearly 3300 UAVs in 2009 and they predicted that by 2018 the yearly UAV expenditure will rise to US$8.7 bn [2].

UAVs are available in many different shapes and sizes which determines their capabilities. They fall under two main categories which are long range or short range. Long range UAVs tend to be fixed wing airframes (see Figure 1) as this structure gives the UAV the ability to fly at high speeds and conduct long endurance missions with a greater payload than a short range UAV. Short range UAVs, which are generally multiple rotary winged airframes (see Figure 2), are slower moving but have the advantage of being able to stop, hover and perch which are vital capabilities within an urban environment. There is one more category which is lighter than air. These UAV also known as blimps have the advantage of longer endurance periods over both fixed wing and multiple rotary wings, but are much slower in comparison. These UAVs are limited to a single use application due to their characteristics which has been noticed by the US Defense Advanced Research Projects Agency (DARPA) who have created the Morphing Aircraft Structures programme to develop a multi-purpose UAV [3].

Figure 1. AeroVironment Raven B UAV.
(www.op-for.com)

Figure 2. AirRobot AR100-B.
(www.ref.army.mil)

Applications

Using an unmanned helicopter has the benefit capturing images, which would normally cost thousands of pounds to achieve with a human scale helicopter. But a modified model helicopter with a camera attached to a camera gimble is one application which a UAV would be more cost effective and safer. Filming a Formula 1 car for example could be dangerous if it were done in a full scale helicopter, as it could distract the driver causing him to loose control (see Figure 3).

The latest UAV from Boeing is called the X45C dubbed the Phantom Ray 2 (see Figure 4). The X45C is also referred to as unmanned combat air vehicle (UCAV). Predecessors of the X45C have successfully demonstrated various battle skills such as precision weapons deployment and various autonomous decisions, but still with a human pilot in the loop.

Law enforcement and rescue services like the fire department are employing UAV's to aid them in the fight against crime and fires. Each UAV is application specific e.g. the fire department uses a Thermal Imaging camera to look into buildings on fire, but only in suitable conditions as most UAVs are prone to failing in harsh weather (see Figure 5).

UAVs have been adopted mainly for military purposes. As these military systems develop in capability, a number of UAV systems with various onboard sensors have been adapted for civilian applications such as earth science research. The sensing systems make these platforms increasingly attractive to the geoscience communities as agricultural tools, as the texture of the land can be analysed to determine whether the crop is healthy [4] (see Figure 6).

Figure 3. Hover Cam Helicopter.
(www.hovercam.com)

Figure 4. Boeing X45C UCAV Phantom Ray 2.
(www.boeing.com)

Figure 5. Microdrone md4-200.
(www.dogonews.com)

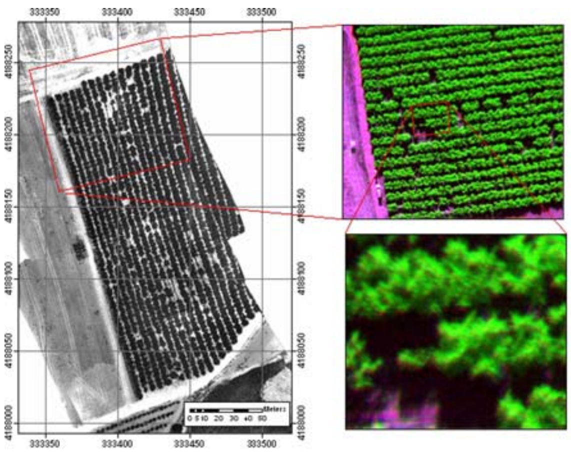

Figure 6. Analysing farmland using thermal imaging.
(http://quantalab.ias.csic.es/)

Current Morphing Air Vehicles

As mentioned before, the push to enhance and develop aerospace/UAV technologies is being lead by various military funded organizations. The Morphing Aircraft Structures (MAS) program from DARPA was created so that a shape-changing UAV combines optimal performance into a single system with perhaps low turning radius, long endurance, increased payload, and high speed-tasks that cannot be efficiently achieved with today's single use structures.

Morphing Wings

Lockheed Martin is one of many organisations with interestingly novel ideas to create morphing UAVs. Their Advance Development Program also known as Skunk Works is responsible for developing a morphing wing structure UAV which not only alters its flight characteristics but also its launch capabilities, called "Cormorant" (see Figure 7). The UAV is released from a submarine missile dock underwater, which then floats to the surface of the water where rocket boosters engage to propel the UAV to normal operating altitude. As the main purpose for this vehicle is for combat, when the UAV needs to attack, its wings structure morphs into a smaller more agile airframe (see Figure 8) while still maintaining its stealth shape. Engineers have looked to biological designs hence the name of the UAV. The Cormorant bird folds its wings when going under water to attack it's pray, as does the UAV.

Similar morphing wing structure has been created by NextGen Aeronautics, where the morphing wing is enough to increase its performance by double from one extreme to the other (see Figure 9). The MFX-1 airframe was 90 kg less than its bigger brother MFX-2 (see Figure 10). MFX-2 is able to morph autonomously in mid-flight within 10 seconds to adjust its wing allowing the area and sweep to be varied independently to optimise the configuration for multiple flight regimes [5].

Figure 7. Lockheed Martin's Cormorant morphing UAV.
(www.popsci.com)

Figure 8. Cormorant morphing.
(www.gdibb.blogspot.com)

Figure 9. NextGen Aeronautics MFX-1.
(www.flightglobal.com)

Figure 10. NextGen Aeronautics MFX-2.
(www.flightglobal.com)

Figure 11. ILC Dover 'The Apteron' UAV.
(www.ilcdover.com)

Another interesting morphing UAV concept comes from the 1950s which involves the idea of inflating and deflating the wings to either gain control or be able to pack away easily for storage and transportation. The inflating and deflating idea comes from the automotive tyre producing company Goodyear which created the 'Inflatoplane' which was a rescue plane that was dropped behind enemy lines for stranded pilots. Goodyear continued to produce these planes for two decades until the inflatable wing idea was adopted into a UAV by ILC Dover called the 'Apteron' (see Figure 11) [6].

Rotor Blades

Using the latest in piezoelectric technology the European Aeronautic Defence and Space Company (EADs) have been able to successfully cut down the noise from helicopter blades by 20% along with cutting the vibration to the cockpit by 90%. This enables a smoother and more controllable flight for the pilot and passengers. They have achieved this by incorporating several Amplified Piezoelectric Actuators, (APA) (see Figure 12) which actively measure and dampen the vibrations caused by spinning the blades at high rpm. The trailing edge of the helicopter blade has 2 to 3 of these flaps which are able to move by 10 degrees. The actuators are controlled via fibre optic cable between the control box which sits above the centre shaft. The actuator reacts so fast that each flap on each blade can open and close once per revolution and 30-40 times when the blades are spinning at 400 rpm which is roughly cruising speed for the helicopter. Piezoceramic actuators are extremely well suited for this application as these actuators are capable of moving high forces in small lengths extremely fast. Any other solution would most likely be improbable and impractical. To move a flap that is 25 cm wide flap on a helicopter would have proved difficult if it weren't for the use of Piezo actuators. The ruggedness and robustness of these actuators makes all this possible [7].

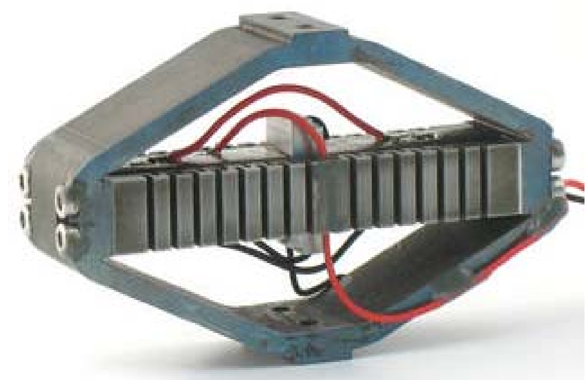

Figure 12. Cedrat APA.
(www.cedrat.com)

Rotor blades on helicopters have also been modified to extend and contract according to the rotor speed. Using centrifugal forces, Professor Farhan Gandhi an Aerospace Engineer at Penn State University has devised a way to uses centrifugal forces to alter the length of helicopter blades. As the rpm increases the blades act like a telescope and extends outward therefore increasing the lifting capabilities in a vehicle such as a helicopter. This would be ideal for a vehicle which needs high lifting power when taking off and lower whilst in forward flight like the V-22 Osprey (see Figure 13) [8].

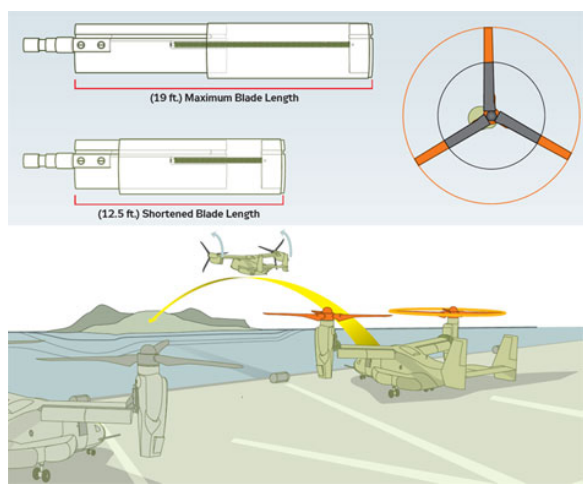

Figure 13. Length Morphing Rotor on V-22 Osprey.
(www.popularmechanics.com)

Future UAV Designs

NASAs Dryden Flight Research Center is keen on the idea of morphing structures which will improve various aspects of flight, whether it is military or civilian applications. They believe that a morphing structure for example could bring reduced noise, increased fuel efficiency, improved ride quality, increased safety, better maneuverability, lower landing speeds, adaptation to shorter runways and extensive versatility. Every aspect of the "plane structure" from wings to the air inlet of the jet engine will be able to morph to better flight as we know it [9].

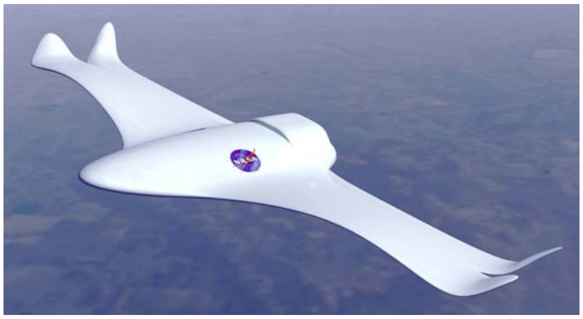

Figure 14. NASA's rendition of a morphing UAV.
(www.dfrc.nasa.gov)

Nobody knows what the future holds for us in terms of UAV technology. All we can do is predict or make assumptions about where we are heading and how we will achieve it. One interesting theory is to look at our past to see our future as we often find patterns in technological advancements [10]. Taking a step back in time and looking at previous attempts to make reconfigurable flying vehicles and not just UAVs, we find one of the earliest reconfigurable designs which never really caught on, but still were able to take off vertically like a helicopter and fly forwards like a plane. The Gyrodyne was designed by a British engineer Dr. James Bennett in the late 1930s. The dream of having the best of both forward and hovering flight seemed like a logical reason to develop such a contraption which also lead to the more modern version of 1930s Gyrodyne. The Boeing V-22 Osprey is multi-billion dollar development project which had its first successful flight exactly 20 years ago, is the only tilt rotor aircraft used by the US military. It cost US$68 m per unit and was used in action by the US Air Force in 2008 (see Figure 15) [11].

Figure 15. Boeing V-22 Osprey.
(www.defenselink.mil)

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