INSECT IMITATING DRONES

What are Undetectable Insect Imitating Drones?

Insects' extraordinary acrobatic abilities aid them in navigating the aerial world, which is full of wind gusts, obstructions, and overall unpredictability. This makes them an excellent inspiration for drones that need to remain undetectable for various purposes. These are also called Micromechanical Flying Insects (MFI). A metal body, two wings, and a control system make up the Micromechanical Flying Insect (MFI), a small UAV (unmanned aerial vehicle). Building insect-like robots can provide a window into the biology and physics of insect flight, a longstanding avenue of inquiry for researchers.

Fig. 1: A Drone that mimics a Dragonfly

Operational Capabilities of Insect Imitating Drones

Drones such as these are under development and are aimed to be used as surveillance techniques where these drones are literally a fly on the wall. The Pentagon is currently working on such drones to aid them in their military operations. Commercial and Military applications for such drones have been identified including operations in hazardous environments for example search and rescue within collapsed buildings or a nuclear plant during a radiation leak.

Features of an Insect Imitating Drone

The US Défense Advanced Research Projects Agency (DARPA) announced the first phase of its nano air vehicle (NAV) program's end in December 2008. The goal was to ensure that the system must have a 20-minute flight duration, be able to endure 2.5 m/s wind gusts, be able to function within buildings, and have a command-and-control range of up to 1 km. Furthermore, the vehicle must be able to hover while transporting a payload. It's no wonder that the scientific community is looking to nature for inspiration in the creation of genuinely miniaturised flying robots, given the spectacular airborne movements found in insects such as bees, flies, moths, and dragonflies. Biomimetic design concepts (those that take their inspiration from nature) are currently being researched.

Advantages and Disadvantages

The Advantages of a micromechanical flying insect are quite obvious, due to their incredibly small size they are excellent for military and rescue operations. They can have medical applications. However, the disadvantages are a main concern while designing a micromechanical flying insect. The disadvantages are listed as below:

1. Complex fabrication: The insect robot design suffers from being very difficult to fabricate because it requires hand assembly of a relatively large number of discrete components. It also consists of several failure-prone steps.
2. Difficulty in landing: The work in demonstrating controlled flight by an 81 mg robot relied on feedback control of its upright orientation using retro-reflective marker-based motion capture. When upright, its long axis extends vertically, raising its centre of mass and making it challenging to achieve a successful landing without toppling over. Successful landings with that design required leg extensions that nearly doubled the vehicle’s size. An alternative is to use switchable electrostatic adhesion for perching and take-offs on vertical or overhanging surfaces, but this adds complexity including a high-voltage source, requires a small amount of additional power to remain attached, and is not required for ground-based landings
3. Limited mobility autonomy: Mobility autonomy for terrestrial robots can be defined as the ability to traverse unknown and non-smooth terrain. Here, we define “mobility autonomy” for insect scale robots as their ability to

traverse locomotion with multiple modes which involve aerial, terrestrial and aquatic locomotion.

Market Survey

A researcher from MIT has developed an insect-sized drone with unprecedented agility and resilience. The aerial robots are propelled by a novel type of soft actuator that can endure the physical demands of real-world flying. He designed a more resilient tiny drone using soft actuators instead of hard, fragile ones. The soft actuators are made of thin rubber cylinders coated in carbon nanotubes. When voltage is applied to the carbon nanotubes, they produce an electrostatic force that squeezes and elongates the rubber cylinder. Repeated elongation and contraction causes the drone's wings to beat fast. These actuators can flap nearly 500 times per second.

The goal of UCB's Biomimetic Milli-systems Lab's micromechanical flying insect (MFI) research is to imitate the flight dynamics of a two-winged fly. The objective is to create a device capable of autonomous flight with a 25mm wingspan and a weight of about 100 milligrams. Since 1998, the research team has been working on raising the lift force generated by a single wing from 500 to 1,400mN by increasing the wing beat frequency from 170 to 270 Hz. This is more than twice as much lift as the last 100mgMFI needs to hover. In the same year, the team demonstrated that a 10mg PZT (piezoelectric) bimorph actuator could deliver 19mJ each cycle of energy (*fig. 2*) with a 450W/kg power output at 270Hz. The smallest available motor, at 70mg, offers a power density of 100W/kg. The team expects that lithium batteries charged by solar cells will be sufficient to power the piezoelectric actuator.

Fig. 2: The piezoelectric thorax

Fig. 4 shows an artist's impression of the MFI. With the aid of funding from DARPA, work at the Micro robotics Lab within the Harvard School of Engineering and Applied Sciences aims to develop autonomous vehicles capable of sustained flight but weighing 1 gm or less and with a wingspan of just a few centimetres. This design also involves a biomimetic approach, whereby the robot broadly emulates the structure and flight of a two-winged fly. After more than seven years of work and studying flight dynamics and improving various components, a flying prototype was finally demonstrated in 2007. This weighed just 60mg and had a wingspan of 3cm (*fig. 3*). Fabricating the device posed a major challenge and rather than employing MEMS technology, which is a costly means of implementing low-volume prototypes, the group developed its own fabrication process. This is based on laser micromachining which was used to produce miniaturised components from carbon fibre and electroactive polymers which move in response to electrical signals. The group is also investigating multiple active materials and compliant actuator morphologies. These include piezoelectric and shape memory materials, dielectric elastomer micro-actuators, active fibre composites and electrochemical actuators. Power is another critical issue and although this prototype was powered externally, the researchers are now working on an onboard power source. A scaled-down lithium-polymer battery would provide less than 5-min flying time but technologies such as piezo electrics may offer better prospects. Indeed, the group is developing milligram-scale power electronic circuits which can step up the output of a 3.7V lithium-polymer battery to over 200V and recover stored energy from the actuator.

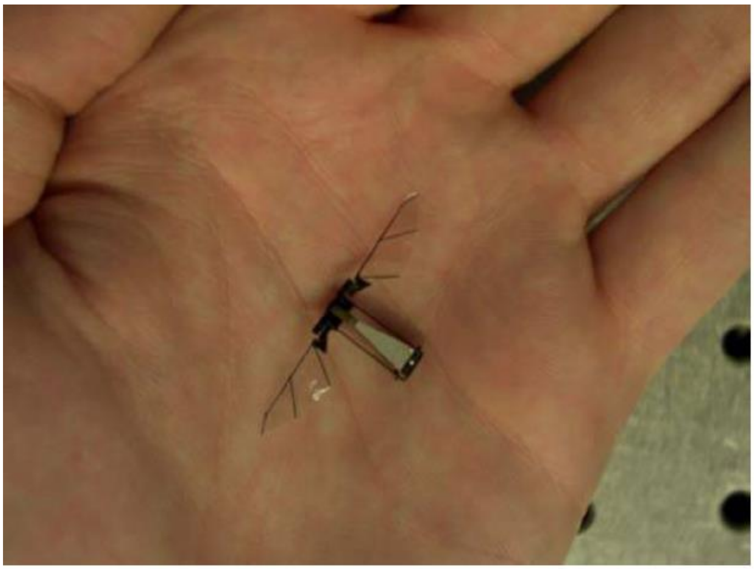

Fig. 3: Harvard Robotic Fly

A different approach is being studied by scientists at the University of Ulm in Germany and the Royal Veterinary College, UK, in that it involves a four-winged device, based on a dragonfly. Dragonflies possess remarkable manoeuvrability and are amongst the few creatures that utilise four independently controlled wings to fly, allowing them to hover, dart, glide, move backward and change directions rapidly. Work is still at an early stage and aims to gain a detailed understanding of the aerodynamics of four-winged flight. The Ulm group has employed a robotic dragonfly about 10 cm tall, immersed it in mineral oil and used laser-based digital particle image velocimetry to measure the aerodynamic forces around the flapping wings (*fig. 6*). While most of the dragonfly's hovering scenarios were not efficient, the team found that if the lower wings are beating slightly ahead of the top wings, the double set is more efficient at generating lift, employing 22 per cent less power to lift the same weight as a single pair. In terms of four- versus two-wing systems for a micro air vehicle, "It's a trade-off" according to Fritz-Olaf Lehmann, a researcher at Ulm who worked on the study. With a four-wing system, the disadvantages are the need for an extra control system and extra power. However, a system with two wings must incorporate ways to change the angle, amplitude, and frequency of the flapping wings to alter the lift, according to Lehmann. Conversely, with four wings, "You can just advance one flight system against the other and then you change lift production." He argues that this makes building a micro air vehicle far easier.

Fig. 4: Robot dragonfly with bubbles illuminated by lasers to show

The Delft University of Technology's Micro Air Vehicle Laboratory has developed a miniature flying robot that resembles a dragonfly (*fig. 7*), although it relies on two wings rather than four. Dubbed the "DelFly Micro", this has a wingspan of 10 cm and weighs just 3 g. The battery contributes1 g; the motor 0.45 g; the camera and transmitter 0.4 g; and the actuator 0.5 g. It is constructed from Mylar foil and balsawood and powered by a 30mAh lithium-polymer battery which is sufficient for 3-min fight and a range of 50 m. During flight, the wings flap at a frequency of 30 Hz. Previous DelFly versions could be controlled from the ground using a joystick and although this functionality is planned for the DelFly Micro, it has not yet been implemented. Autonomous flight without any intervention from the ground is the eventual goal of the project.

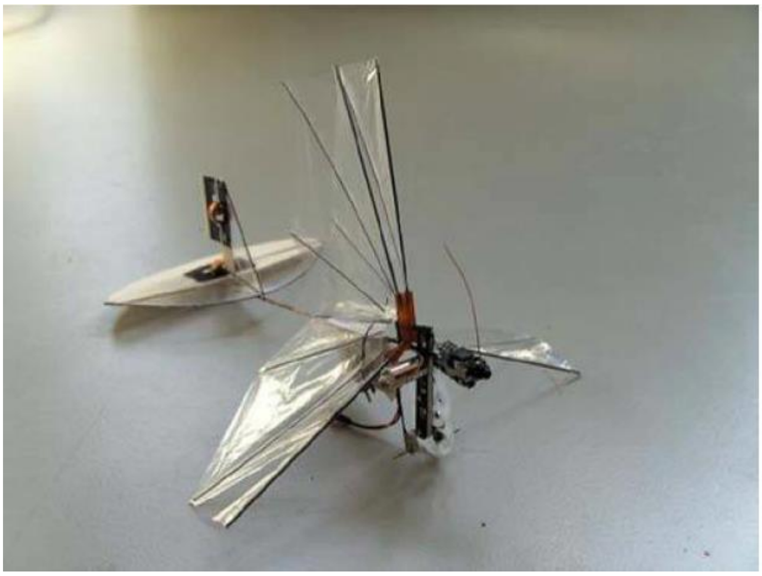

Fig. 5: The DelFly Micro

Another example of European research is the Bioinspired Vision-based “Micro-flyers” work by the Intelligent Systems Laboratory at the Swiss E ´ Cole Polytechnique Fe´de´rale de Lausanne. Rather than developing a micro flying machine, the aim is to use a small, lightweight flying device to gain a better understanding of the mechanisms and strategies required to fly in confined environments. The project’s stated goal is: Designated the “MC2”, the device is based on a commercially available 5-g indoor flyer produced by DIDEL SA which features a 4mm geared motor, *fig. 6*, see (a) and two magnet-in-coil actuators (b) which control the rudder and the elevator. The total weight reaches 10 g when fitted with the electronics required for autonomous navigation. This consists of a 8-bit microcontroller (c) running at 32 MHz, a Bluetooth radio module for parameter monitoring and two camera modules, each comprising a CMOS linear camera and a MEMS gyro. One of these modules (d) is oriented forward with its rate gyro measuring yaw rotations and is used for obstacle avoidance. The second (c) is oriented downwards, looking longitudinally at the ground, while its rate gyro measures rotation about the pitch axis. Each of the cameras have 102 pixels spanning a total field of view of 120^{o}. The MC2 is equipped with an anemometer (e) consisting of a free propeller and a Hall effect sensor to measure its airspeed. Once released into its test environment, the MC2 would fly for a few minutes while avoiding collisions with surrounding surfaces such as walls and floor until it was caught by hand. The 65mAh lithium-polymer battery (f) allows a flying time of approximately 10 min. These results show that full autonomy can be achieved through vision-based collision avoidance techniques and the next steps are achieving autonomous take-off and landing and the replacement of the onboard cameras with custom VLSI “neuromorphic” vision chips (*fig. 7*) in order to adapt to a wider range of visual contrasts and background light intensities. These chips are being developed by the Institute of Neuroinformatics, a research institution jointly owned by the University of Zurich and the Swiss Federal Institute of Technology.

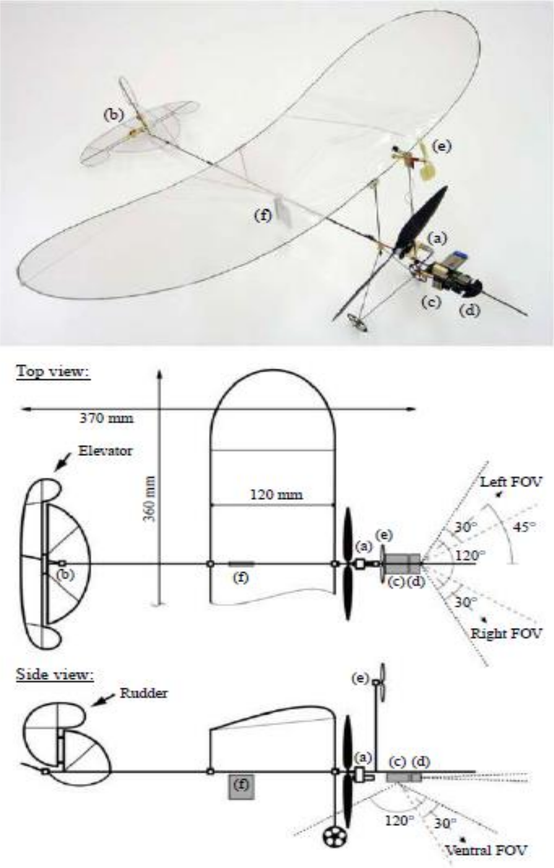

Fig. 6: Photograph and diagrammatic views of the MC2

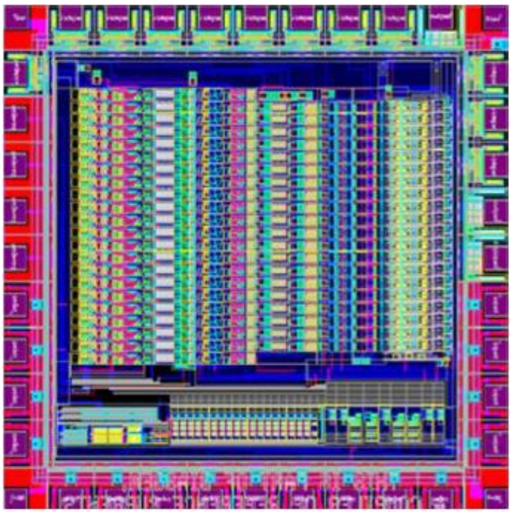

Fig. 7: Neuromorphic vision chip being developed by the Swiss

Challenges expected to be faced during the design of a Micromechanical Flying Insect

- The small size and the nature of forces at play
- Need to build the whole system without any rotary motors, gears, and nuts and bolts, which are not viable on such a small scale.
- At a micro scale, a small amount of turbulence can have a dramatic impact on flight
- Modelling turbulence accurately and making sure that the MFI is structurally sound when it encounters turbulence is a massive task.
- The MFI is too small to incorporate the smallest encapsulated microchips, meaning there is no way for the MFI to make decisions on its own.
- The final challenge that will be faced while designing an MFI is figuring out a viable power supply which will fit the size limitations that exist and power the MFI through the entirety of its mission.

These issues need to be resolved in order to develop a process flowchart for the design and development of an MFI.