Cyclogyro Flying Robot Improves its Angles of Attack

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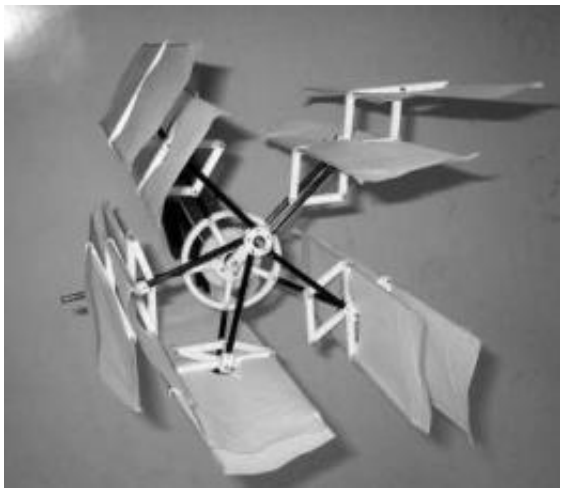

A prototype design of the cyclogyro craft with five pantograph-based variable wing units. Image credit: Naohiro Hara, et al. (c)2009 IEEE.

(PhysOrg.com) -- In the past few decades, researchers have been investigating a variety of flying machines. Most studies have focused on improving the flying performance of standard flying mechanisms, rather than developing innovative flying mechanisms.

But one intriguing flying mechanism that has received relatively little attention is a horizontal-axis rotorcraft - or "cyclogyro" craft. First proposed in the 1930s, a cyclogyro is a unique mechanism of generating lift forces, being propelled by horizontal rotating wings. Unfortunately, the few prototypes that were built at the time were unsuccessful at flying.

The essential flying principle of the cyclogyro rotorcraft is that, as the wings rotate, their angle of attack must be altered so that the wings can lift and thrust at the appropriate times in the cycle. Designing such variable wings that can alter the angles of attack has proven difficult.

But recently, a team of engineers consisting of Naohiro Hara, Kazuo Tanaka, and Hiroshi Ohtake from the University of Electro-Communications in Japan, and Hua O. Wang of Boston University in the US, have developed a cyclogyro flying robot with a new kind of variable wing mechanism. The mechanism is based on a pantograph, which is a mechanical linkage that was originally developed in the 17th century as a drafting tool for copying and scaling line drawings.

In the flight performance experiment, the cyclogyro robot created enough lift force to fly. Image credit: Naohiro Hara, et al. (c)2009 IEEE.

As the engineers explained, a key feature of the pantograph-based variable wing mechanism is that it not only changes the angles of attack, but also expands and contracts according to wing positions. By creating larger lift forces and smaller anti-lift forces, this design could provide greater flying efficiency, as well as high maneuverability.

The group's study, "Development of a Flying Robot With a Pantograph-Based Variable Wing Mechanism," will be published in an upcoming issue of *IEEE Transactions on Robotics*. The mechanism is an extension of two of the authors' earlier prototype designed in 2006, which demonstrated that a cyclogyro-based flying robot could generate enough lift force to fly and carry a very small (10 g) payload. With the new mechanism, the researchers hoped to improve the efficiency. Through simulations and experiments, they focused on demonstrating the possibility of a flying robot with a pantograph-based mechanism.

The engineers explained that, in the downstroke motion, the new mechanism can generate heavy lift forces in the upward direction by expanding the wings with larger angles of attack. Conversely, in the upstroke motion, the mechanism can reduce anti-lift forces in the downward direction by contracting the wings with smaller angles of attack. Due to this folding up motion of the wings, which creates a larger wing area in a small space, the rotorcraft can get a larger lift force compared with the authors' previous strategy.

The simulations and experiments (in which the rotorcraft was tethered for stability) showed that the robot could generate a lift force exceeding its own weight. Not only could this force allow the robot to fly, it means the robot could carry a significant payload (155 g). Accounting for the robot's four rotors, the engineers hope that it may be possible to fly the robot with a battery, some sensors, and even a control board (currently, the robot receives power from an external supply).

In the future, the engineers plan to develop a detailed aerodynamic analysis of the wing motion. Eventually, they hope to develop a full-body flying robot with the optimal parameters, including four sets of pantograph-based variable wings and a stabilizing controller. With its ability to rise, hover, and go backward, a cyclogyro flying robot could one day operate as a highly maneuverable micro air vehicle.

More information: Hara, Naohiro; Tanaka, Kazuo; Ohtake, Hiroshi; and Wang, Hua O. "Development of a Flying Robot With a Pantograph-Based Variable Wing Mechanism." *IEEE Transactions on Robotics*. To be published.