Researchers develop transient bio-inspired gliders from potato starch and wood waste

April 18 2023, by Andrea Six

Ephemeral data collectors: Bio-gliders are dispersed over a forest by a drone. When they reach the ground, they transmit environmental data until they are eventually decomposed by soil organisms. Credit: Empa

Their task is to monitor the condition of ecosystems, for instance in the forest floor—and crumble to dust when their work is done: bio-gliders modeled on the Java cucumber, which sails its seeds dozens of meters through the air. Empa researchers have developed these sustainable flying sensors from potato starch and wood waste.

Alexander von Humboldt, Charles Darwin and Ernest Shackleton set out on years of arduous voyages of exploration to gather spectacular, previously unknown impressions. Today, the pioneers of modern environmental observation are to be succeeded by faster, contemporary data collectors that record important eco-parameters in real time and without any risk.

Empa researchers at the Sustainability Robotics laboratory in Dübendorf are therefore developing low-cost, sustainable sensors and flying devices that can collect environmental data in an energy-efficient, close-meshed and autonomous manner even in inaccessible areas, so-called bio-gliders. The ingredients: potatoes, some wood waste and a dyer's lichen.

Litmus test in the forest

Like leaves tumbling to the ground in autumn, they sail silently to the forest floor: bio-gliders with built-in sensors. Yet the "bio" label applies to the slender flying devices in two ways: They are inspired by biology, as they are modeled on the flying seeds of the Java cucumber, yet they are also biodegradable. Once a drone has released the smart sensor seeds, they report data on, say, soil moisture and acidity until they eventually decay and become one with the forest floor.

Empa researcher Fabian Wiesemüller and Mirko Kovac's team from the Sustainability Robotics lab want to use the data from the smart seeds to monitor the condition of the forest soil and its biological and chemical balance. A first sensor is now used to measure the pH value with a classic litmus test.

Here, the lichen-derived dye reacts to acid with a color change from purple to red. "The color change of the sensor on the forest floor is then registered by a drone flying over the area," Wiesemüller explains.

A sensor in full bloom

To ensure that the sensor is protected until it is used and only collects data at the crucial moment, it is covered by a protective film. This is a tricky "contra hood" that releases the sensor as soon as rain falls: during work breaks, it assumes a robust protective posture. As soon as the sensor is to start its operation, however, the protective film reacts very sensitively. If rain or humidity is in the air, it opens like a flower.

Together with Gustav Nyström's team from Empa's Cellulose & Wood Materials laboratory, the researchers developed this protective mechanism based on nanofibrillated cellulose from wood residues, which was processed with gelatin to form a fine polymer film that reacts to atmospheric moisture. Once the rain clouds have cleared, the polymer bloom closes after about 30 minutes until the next cycle of duty.

To ensure that the "blossom" opens symmetrically, the polymer film is also coated with a very fine layer of shellac, a natural resin-like substance excreted by plant lice. It prevents the polymer material from expanding unevenly when exposed to moisture.

On the wings of a … potato

The transport vehicle for the biosensor is a glider whose material consists of conventional potato starch, comparable to edible paper. This means that the glider can simply be printed out and pressed into the shape of the Java cucumber seed. Including the sensor, the glider weighs just 1.5 grams and has a wingspan of 14 centimeters.

"The biologically inspired design is intended to enable the glider to descend for as long as possible," says robotics researcher Wiesemüller, explaining the choice of glider geometry. In the drone flight arenas at Empa in Dübendorf and at Imperial College London, Wiesemüller was finally able to optimize the flight behavior and stability of the first prototypes. In the flight arena, the bio-glider manages to achieve a glide ratio of 6. This corresponds to a horizontal distance of 60 meters when the glider takes off from a height of 10 meters.

When the ultralight measuring device reaches the ground, a race against time sets in. While the sensor measures the pH value every time it rains, nature gets to work on it. After seven days under laboratory conditions, soil organisms have already decomposed the wings. After another three weeks, the sensor falls apart. This is how the natural components of the bio-glider find their way back into nature.

According to Wiesemüller, the acid sensor is only an initial proof-of-concept that will be followed by other types of sensors that can determine the condition of trees, water and soil in real time.

Dust to dust

Currently, the researchers are going one step further. Their goal is to record the effects of climate change on different habitats using completely biodegradable sensor drones. In the spirit of "digital ecology," such robots will allow for accurate predictions of the state of the environment and appropriate preventative measures, and then decompose into their parent materials in nature.

So far, not all parts of such environmental drones are available in high-quality biodegradable versions. Empa researchers are now working in interdisciplinary teams on flying drones with an environmentally friendly framework based on highly porous cellulose and gelatin materials. The findings from the bio-glider project are also being incorporated here.

Bioinspired robots

They are to repair buildings and measure environmental pollution in inaccessible regions—for these tasks, the artificial helpers are to be inspired by nature. The biologically inspired flying objects still have a lot to learn from their role models in order to be able to act independently in a complex environment.

After all, nature has had hundreds of millions of years to perfect the characteristics of living creatures. For the biodegradable sensor glider, the Empa researchers took the Java cucumber, Alsomitra macrocarpa, as their model. The Asian liana lets the wind disperse its seeds that are equipped with transparent wings. Like the original, the smart sensor seeds have a wingspan of 14 centimeters. Instead of the seed at its core, the bio-glider carries a sensor for collecting environmental data.

The research is published in the journal *Frontiers in Robotics and AI*.

More information: Fabian Wiesemüller et al, Transient bio-inspired gliders with embodied humidity responsive actuators for environmental sensing, *Frontiers in Robotics and AI* (2022). DOI: 10.3389/frobt.2022.1011793

Provided by Swiss Federal Laboratories for Materials Science and Technology