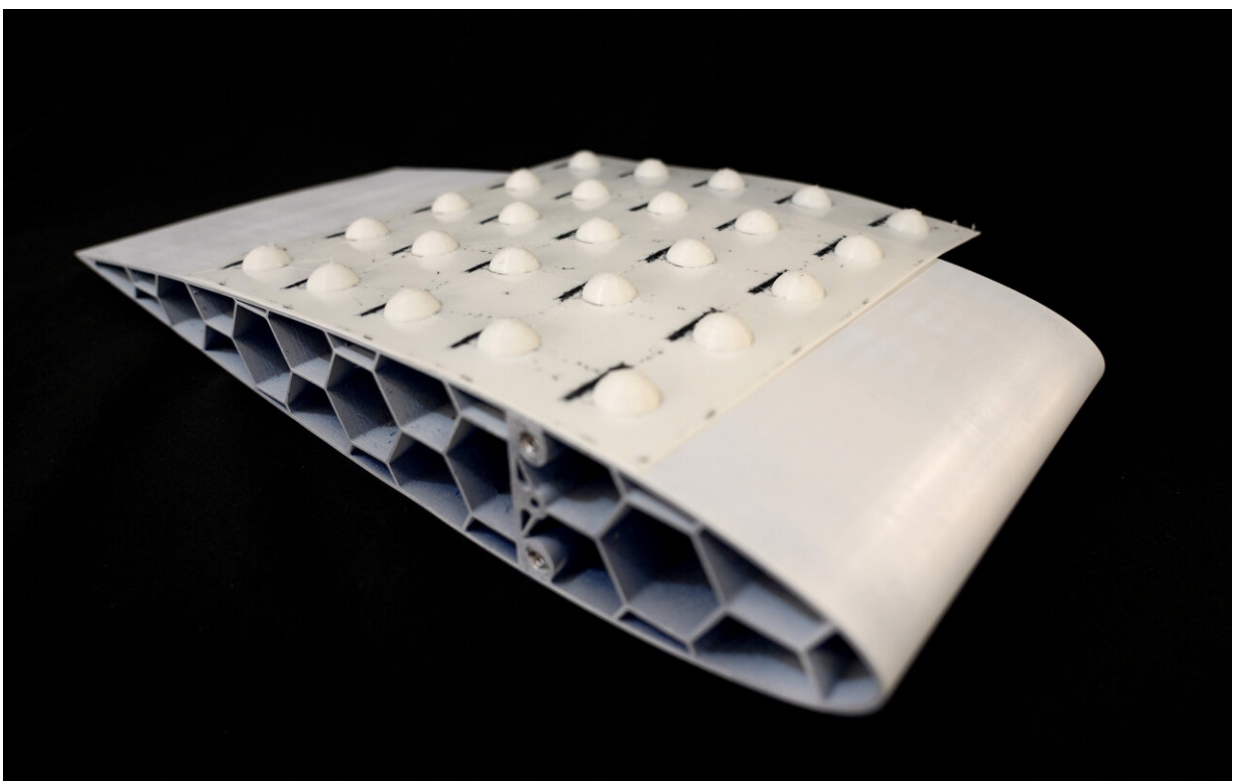


Borrowing a shape from a to-go cup lid, a drone wing could learn how to sense danger faster

October 26 2022, by Kayla Wiles



Researchers have discovered a new possible use for the dome shape that you would find on a to-go cup lid. Patterns of these invertible domes on a drone's wings would give it a way to remember in microseconds what dangerous conditions feel like and react quickly. Credit: Purdue University/Jared Pike

The oddly satisfying small domes that you press on your soda's to-go cup lid may one day save a winged drone from a nosedive.

Patterns of these invertible domes on a drone's wings would give it a way to remember in microseconds what dangerous conditions feel like and react quickly. The study, conducted by researchers at Purdue University and the University of Tennessee, Knoxville, is among the first demonstrations of a metamaterial that uses its shape to learn how to adapt to its surroundings on its own. The paper is published in the journal *Advanced Intelligent Systems*.

Unlike humans and other living beings, autonomous vehicles lack ways to filter out information they don't need, which slows their response time to changes in their environment.

"There's this problem called 'data drowning.' Drones cannot use their full flight capability because there is just too much data to process from their sensors, which prevents them from flying safely in certain situations," said Andres Arrieta, a Purdue associate professor of mechanical engineering with a courtesy appointment in aeronautical and astronautical engineering.

Dome-covered surfaces that can sense their surroundings would be a step toward enabling a drone's wings to feel only the most necessary sensory information. Because it only takes a certain minimum amount of force to invert a dome, forces below this threshold are automatically filtered out.

A specific combination of domes popped up and down at certain parts of the [wing](#), for example, could indicate to the drone's control system that the wing is experiencing a dangerous pressure pattern. Other dome patterns could signify dangerous temperatures or that an object is approaching, Arrieta said.



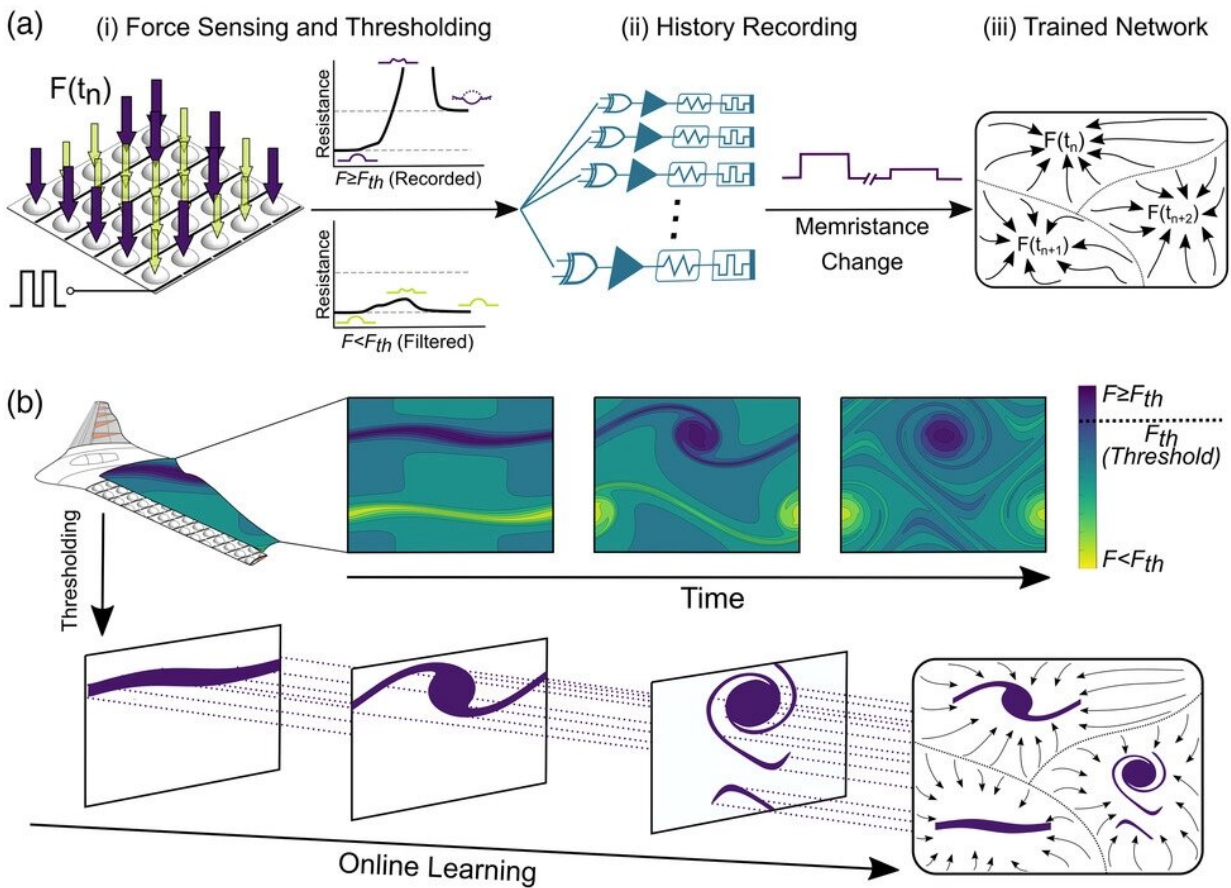
Arrays of domes on a drone wing may help it to detect information from its surroundings only when necessary. Credit: Purdue University/Jared Pike

Giving drones associative memory through feel

It may seem strange that an invertible dome could give [memory](#) cues to a drone wing for dangerous conditions, but humans and animals also use unrelated concepts to recognize relationships. This learning strategy is called [associative memory](#). When you have forgotten the name of a place, for example, you might use a detail such as the color of a building to remember it. Recalling a partial version of the memory allows you to construct a much more complete version of that memory.

Arrieta's lab investigates ways that an engineered material's shape could help it to compute and process information. His lab frequently takes inspiration from how spiders and other animals use their anatomical shapes to sense and understand the world around them.

For decades, electronics have been designed to save and retrieve images by encoding information in patterns of black or white pixels as zeroes or ones. Because a dome can adopt only two states—popped up or popped down—these states can act like zeroes and ones to create spatial patterns for building associative memory.



a) i) Neuromorphic metamaterial composed of mechanosensing unit cells with inherent filtering, transduction, mechanoelectric signal amplification, and

memory capabilities. ii) The bistable units transduce mechanical inputs exceeding a desired amplitude threshold into electrical resistance changes mediated by the dome stable state-dependent piezoresistive sensor. iii) These characteristics allow for realizing physical Hopfield networks capable of encoding several spatiotemporal patterns as attractors of the network's interaction matrix, the synaptic weights of which are stored as the final (current) states of the memristors. b) The physical Hopfield networks enabled by our neuromorphic metamaterials are trained online by continuously changing distributed mechanical inputs (such as pressures over wings). This allows for realizing substrates exhibiting event camera-like tactile perception[60] with online learning and reduced external memory as several patterns can be retrieved from the memristors' latest states, i.e., the current memristive states encode the time history of loading as distinct patterns stored in the Hopfield network's connectivity matrix. Credit: *Advanced Intelligent Systems* (2022). DOI: 10.1002/aisy.202200158

Arrieta and his team showed in the study that when a certain level of force inverts a dome, sensors embedded into the flat part of a metamaterial sheet surrounding the dome detect the change in shape. An [electrical signal](#) then triggers a memory device called a memristor to make a record of the force and where it was detected on the sheet. With each instance of an inverted dome, the metamaterial learns to remember the pattern that a certain level of force creates on its surface.

In practice, a drone wing would be able to quickly recall a pattern associated with a dangerous condition because the metamaterial keeps a record of all its "partial memories" from inverted [dome](#) patterns as a single "complete memory" that these patterns create altogether. Based on this study, the researchers believe that the metamaterial wouldn't need to "buffer" to recall information that it stores within itself over time.

Since the metamaterial can be manufactured with existing methods,

these domes can easily cover a large surface area like a drone's wing, Arrieta said. Next, the researchers will test how the material responds to its surroundings based on information it learns from the domes. Arrieta anticipates that it will be possible to build a drone wing using this material design in the next three to five years.

More information: Katherine S. Riley et al, Neuromorphic Metamaterials for Mechanosensing and Perceptual Associative Learning, *Advanced Intelligent Systems* (2022). [DOI: 10.1002/aisy.202200158](https://doi.org/10.1002/aisy.202200158)

Provided by Purdue University

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