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Technical Perspective Localizing Insects Outdoors

By Prabal Dutta

THE VISION OF tiny, flying robotic insects has captured the imagination of researchers in many disciplines. Some have sought to create entirely synthetic robotic creatures while others have chosen to weave and deeply enmesh biological sensing and actuation with electronic computation and controls. The following paper by Iyer et al. takes a different approach. It neatly separates the problems of locomotion, solved using existing biology, and the problems of sensing, localization, and communications, solved using commercial microelectronics and new algorithms, packaged into a tiny payload. These two halves—one biological and one electronic—are then simply glued together to realize a cyborg bumblebee with a mind of its own carrying sensors on our behalf.

Realizing this exciting vision requires solving myriad research and engineering problems, but perhaps none more daunting than how to localize a small and fast-moving bumblebee at a range of tens of meters. The problem is particularly challenging because of the severe and unforgiving size, weight, and power (SWaP) constraints on payload capacity. A key contribution of the accompanying work is a novel method for low-power, mid-range, outdoor localization that estimates the angle-of-departure of signals from several multi-antenna access points in clear line-of-sight settings, as might be typical on farms and fields.

This technical feat is accomplished by having a pair of antennas transmit nominally identical signals that combine at the receiver. The difference in the path length between the two antennas and the insect manifests as an amplitude and phase difference in their sum at the receiver, which is also attenuated by the path loss the signals both have in common for the line-of-sight path. If this (unknown) path loss is normalized by sweeping the phase

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of one signal, which allows the maximum strength of the received signal to be recovered, then the path loss can also be determined and factored out. Finally, the effect of multipath is reduced by using multiple access points and multiple antenna pairs at each access point.

Going far beyond just the theory, or even a benchtop proof-of-concept, the authors build a low SWaP circuit (just 39 mm², 102 mg, and 138 μA) that realizes this idea, augments it with sensors and backscatter communications using a custom-designed antenna, and uses it to demonstrate how a bumblebee-based sensor can sample a large field and download data upon return to the hive. The prototype integrates temperature, humidity, and light sensors with a microcontroller that offers 32 KB of memory for sensor and location data storage, along with a 1 mAh battery, that weighs 70 mg, to yield a system that can run for an impressive seven hours! Looking ahead, the authors report that RF or solar energy harvesting could enable indefinite lifetime, especially when combined with ultra-low power custom electronics. 

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