ApiSense: A Weather-Aware Multimodal Framework for Environmental Pesticide Contamination Detection Using Honey Bees as Biosensors

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With 5.6 billion pounds of pesticides entering ecosystems annually, traditional monitoring methods such as soil and water sampling cannot cover large areas, cost $500–600 per sample, and take weeks to return results. Meanwhile, honeybees forage 80 square kilometers daily and are sensitive to sublethal concentrations of pesticides. While researchers have shown that pesticides affect foraging behavior, few studies use foraging behavior to detect pesticide exposure. Colony acoustics have been applied to detect air pollutants, but they ignore how weather independently affects acoustic signals. I present ApiSense: the first weather-aware multimodal system that uses honeybees as biosensors to detect pesticide contamination. By isolating toxicological behavioral responses from weather responses and analyzing how foraging and acoustic signals interact over time, ApiSense detects sublethal pesticide exposure across agricultural landscapes. To validate this, I applied bifenthrin at 50 ppb across 16 hives over 15 days, collecting 20,160 samples. ApiSense reached 80.2% accuracy within 3 days of exposure and 79.6% mean accuracy, outperforming every baseline by at least 6.7%. Independent lab testing on pollen confirmed ApiSense's detections. I identified wingbeat stability and foraging return rate as early behavioral biomarkers of sublethal exposure, preceding disrupted foraging schedules and homing failure. This three-phase progression aligns with established neurotoxicology: motor control fails first, circadian rhythms destabilize next, and colony loss follows. At $120 per hive with day 3 detection, ApiSense can be deployed across 2.7 million existing U.S. beehives as a distributed pesticide monitoring network that no traditional method can replicate.

Awards Won:
Second Award of $2,400