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Wings of Change: Drones Revolutionizing Pollination Practices

Jennifer Minhaj[1], Pronoy Protim Sarma[1] and Raktim Jyoti Deka[1]

[1]B.Sc. (Hons.) Agri. 4th year student, SCS College of Agriculture, Assam Agricultural University, Rangamati, Dhubri, Assam

*Corresponding Author: jenniferminhaj03@gmail.com

Abstract

Robotic bee drones are a potential solution to the declining bee populations that threaten global agriculture and ecosystems. Mimicking natural pollination processes, these autonomous drones navigate using AI and sensors to precisely transfer pollen between flowers. This technology offers several advantages including increased efficiency, 24/7 availability, and reduced reliance on natural pollinators, potentially leading to higher crop yields. However, challenges remain such as large-scale deployment, economic considerations, environmental concerns about discarded materials, and ethical considerations regarding potential misuse. Despite these challenges, ongoing research shows promise for bee drones to revolutionize pollination processes, enhance crop yields, and improve ecosystem monitoring. Collaborative efforts across various sectors are crucial to ensure the responsible development and implementation of this technology for a sustainable future.

Introduction

Robotic pollinators are developed as a solution to declining bee populations and environmental challenges. With the ability to mimic pollination, these robots ensure crop and plant reproduction. As real bees face threats, these technological helpers safeguard agriculture, promoting sustainability and food security in a changing ecosystem. The decline in bee populations poses a critical threat to global agriculture and ecosystems. As natural pollinators face challenges like habitat loss and pesticides, there's an urgent need for alternative methods. Robotic bee pollinators emerge as innovative solutions, addressing the vital role bees play in plant reproduction. By mimicking their pollination activities, these robots ensure the continued growth of crops and maintenance of biodiversity. This technological intervention becomes crucial for sustaining agriculture and food security, mitigating the impact of declining bee populations on our delicate ecosystem.

Design And Functionality

Robo-bees are small autonomous aerial vehicles, that range in size from a few centimetres to roughly 15 centimetres. Weight of such a bee is about 10 grams, which are efficiently do pollen transfer between individual flowers. Its three basic parts are the colony, the brain, and the body. The brain is made up of “smart” sensors and control electronics that act as the bee’s eyes and antennae, allowing it to sense and react to its surroundings dynamically. The colony serves as a coordinator of many independent bees like these, enabling them to work as a single, cohesive unit. The body is made up of a small, seamlessly integrated power source that enables the bees to fly on their own.

As for functionality, each drones have four propellers that help them stay in the air. When all propellers push equally, the drone hovers in one place. To go in a certain direction, some propellers slow down, making the drone move that way. If all propellers spin the same, the drone spins too. To stop this, two spin one way, and two spin the other. The drone's "brain" is the flight controller, which keeps it still when no one is commanding it what to do. When the pilot gives a command, like "go forward," the flight controller figures out how fast each propeller should spin. That's how a drone works.

Researchers also introduced a "search mode" for the identification of flowers targeted for pollination using a bee robot drone. In this mode, the drone autonomously locates flowers through flight, employing AI classification technology. For accurate autonomous flight, motion-capture schemes are utilized for positioning. Robot Operating Systems (ROS) that integrate location and ROS for autonomous flight control are used to control the drone's flight. In order to efficiently pollinate flowers while in flight, the drone uses the same autonomous flight control system in the pollination mode. It also has a specially designed vibrator device.

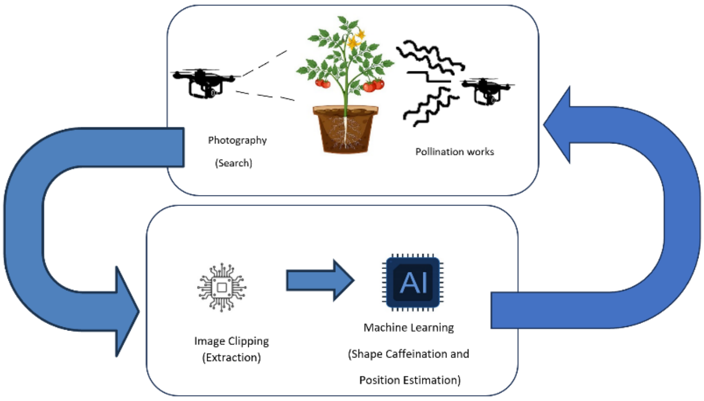

Fig. 1: Pollination system configuration using small drones

Field testing and research findings

In Israel, there is a startup company, BloomX, which uses artificial intelligence and elements of biomimicry to pollinate crops. The machines of this company are capable of imitating the best natural approach of pollinating specific crops. There are mainly two approaches, "Cross Pollination Mechanism" it collects pollen grain using a electric charge from a flower and apply it to another while passing between rows of crops. This approach is similar to how honey bees pollinate. The second approach uses vibration at the base of a plant to initiate the release of pollen and facilitate pollination. The aim of the company is not to completely replace the natural honey bees, rather its devices offer more efficient pollination methods, reducing dependence on commercial honeybees [1]. BloomX's technology has been assisting in growing of avocados as well as blueberries in South America since 2020. The company is also doing its research to launch machinery which are highly specific to increase the productivity of greenhouse for increasing demand in food production.

Other companies are also trying to integrate machine learning and artificial intelligence to assist pollination process. Among them, Blue white Robotics is a prominent name. This company has developed drones to pollinate date palms, apples, almonds in the Arabah, Northern Israel and California respectively [2]. Another such company is Arugga, which is reportedly the first company to produce tomatoes commercially under greenhouse using robotic pollination. AI-powered robot scans the flowers to identify its suitability for pollination, can move up and down in rows of tomato plants to adjust its heights to the flowers, and then bursts the flowers with calculated and just enough streams of air to initiate pollination. West Virginia University has also developed a robot Bramble Bee, which is being used in pollination of blackberries using similar methods [3].

Advantages

i) Increased Efficiency: Bee drones can be programmed to pollinate specific areas of crops efficiently, making sure each flower receives adequate pollination. This precision can lead to higher crop yields and improved quality.

ii) 24/7 Availability: Unlike honeybees, which are active only during certain times of the day and are affected by weather conditions, bee drones can operate round the clock and are not limited by weather constraints. This allows for consistent pollination regardless of environmental factors.

iii) Reduced Dependence on Natural Pollinators: With declining populations of natural pollinators such as bees due to factors like habitat loss and pesticides, bee drones offer a reliable alternative for crop pollination. They can reduce dependency on natural bees for agricultural productivity.

iv) Customizable Pollination Patterns: Bee drones can be programmed to follow specific pollination patterns tailored to the needs of different crops. It ensures optimal pollination coverage and can adapt to the varying requirements of different plant species.

v) Minimized Risk of Disease Spread: Unlike natural pollinators that may inadvertently transmit diseases between plants, bee drones can be sterilized between pollination sessions, reducing the risk of disease spread among crops.

vi) Data Collection and Monitoring: Bee drones equipped with sensors and cameras can collect various data on crop health, pollination rates, and environmental conditions. This information can be used to optimize farming practices and improve overall agricultural productivity.

Limitations

(i) High numerical requirements: A very large number of insects are needed for pollination. To maintain the current level of coffee production worldwide, at least 22 trillion pollinator visits to coffee plant flowers are required annually. A discharge of this magnitude of robo-bees into the wild would be a logistical nightmare.

ii) Cost considerations: Metals are needed for electronic components in robot bees, whereas polymers and composites (such as silicon, lithium, etc.) are needed for structural sections. To manufacture these robo bees, the expenses of extracting and processing such materials would not be viable. Additionally, recycling the robots' e-waste materials will be a costly endeavour.

iii) Ecological and environmental concern: whereas robo-bees cannot feed fish, birds, or lizards, bees do. If consumed, lithium batteries are directly harmful. Furthermore, insect predators have not evolved to differentiate themselves from the insects they prey on. Furthermore, when robo-bees corrode, a variety of dangerous chemicals will be released if they malfunction while operating, as a result of erratic weather, or if they lose communication with the base. Toxins generated by this corrosion will seep through the ground or discharge across the surface, gathering in streams and washing up on beaches. This artificial bee trash will be even worse than plastic or even micro-plastic waste because of this.

iv) Ethical concern: These robo-bees' software imitates nano-swarms. It's alarming that swarming autonomous vehicles may be turned into weapons. Considering that robot swarms have the potential to be an unpredictable, unavoidable mass surveillance instrument.

Integration With Traditional Pollination Practices

Bee drones offer a promising avenue for complementing or even replacing traditional pollination methods in agriculture. These robotic pollinators can help mitigate the decline in bee populations and address concerns about pollination efficiency. For instance, they can navigate challenging environments and work during inclement weather conditions when natural pollinators might not be active. However, integrating bee drones into existing agricultural practices poses several challenges. One significant hurdle is the need for technological advancements to ensure the drones effectively mimic the behaviour of natural pollinators and accurately transfer pollen between flowers. The cost of implementing the suggested drone-based pollination method is higher than that of traditional ways. Moreover, it is a complicated technology with installation and maintenance problems. On the other hand, pollination is simple after installation, and the fruit yield and dependability are comparable to those of manual pollination or bees. Farm managers can spend less time on the farm and no longer need to hire more employees. Short flight times owing to the drones' small battery capacity, battery charge management for seamless operation, service life, and cost effectiveness are additional difficulties. On the other hand, operational problems are challenges that need to be overcome before the system can be sold as a product and offered as a service. In spite of these obstacles, continuous research and development endeavours are directed towards enhancing bee drone technology and streamlining their incorporation into conventional pollination methods. While a fully functional robotic pollination swarm might not come about for years, there have been encouraging technological developments in this area. As technology and nature intertwine, we continue to witness groundbreaking innovations that benefit various industries, including agriculture.

Conclusion

In contemplating the future role of Bee Drones in agriculture and ecosystem management, several exciting prospects emerge alongside formidable challenges. These miniature aerial vehicles hold promise in revolutionizing pollination processes, augmenting crop yield, and enhancing biodiversity monitoring. For instance, the recent integration of Bee Drones in almond orchards in California showcased their potential in pollination services, mitigating the decline of natural bee populations. Moreover, in ecosystem management, Bee Drones equipped with advanced sensors offer real-time data collection for assessing habitat health and detecting environmental changes. Technologically, enhancing drone autonomy and durability remains imperative to ensure efficient operation in diverse environments. Regulatory frameworks need refinement to address airspace congestion, privacy concerns, and safety standards. Moreover, societal acceptance and education initiatives are pivotal in dispelling misconceptions and fostering trust in Bee Drone technology. As we navigate these challenges, the collaborative efforts of stakeholders across sectors will be essential in realizing the full potential of Bee Drones in transforming agriculture and ecosystem management.

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