The bee.directory project: “The Power of Decentralization, Machine Learning and Artificial Intelligence in saving Wild Pollinators”

Designing a decentralized system that uses AI and machine learning algorithms to detect and recognize bees and pollinators, providing crucial data for conservation efforts.

About the author

Professional Summary

Passionate and dedicated professional with over a decade of experience in designing and developing cutting-edge bee monitoring systems. Specialized in harnessing IoT technologies and predictive analytics to contribute to global bee conservation efforts. Adept at developing innovative solutions to address challenges in pollination processes and combat colony mortality.

Commenced engagement with bee-monitoring systems in 2012, assuming the role of a programmer for the preeminent remote hive monitoring system. Spearheaded the development of a cutting-edge platform that seamlessly integrates colony acoustics monitoring with comprehensive metrics such as brood temperature, humidity, hive weight, bee counts, and real-time apiary weather conditions. This pioneering system delivers crucial insights into colony status, thereby contributing to the advancement of precision apiculture practices.

Key Achievements

Spearheaded the development of iBumble.io, an IoT system revolutionizing pollination processes by providing unprecedented measurability and controllability over bumblebee activities.

Led the design and development of iBee.io, an advanced honeybee hive monitoring system, contributing to enhanced hive management and improved bee health outcomes.

Played a pivotal role in the IoBee project, a European Union-funded initiative dedicated to fighting Colony Mortality through IoT. Developed systems featuring optoelectronic sensors for insect count and species identification.

Introduction

Despite their vital role as pollinators, wild bees often face neglect, with domestic honeybees garnering more attention. Native bee species confront threats like habitat loss, disease, and pesticides, contributing to documented declines.

Studies emphasize the crucial contribution of native bees to both ecosystems and agriculture, pollinating over 80% of flowering plants and 75% of global food crops. Native bees help to pollinate the three-quarters of crop species that rely on pollinators, which amounts to one-third of global crop production by volume.
Wild pollinators play a crucial role in the survival of our ecosystem, agriculture, and food production.

Research reveals economic impacts, with wild bees responsible for over $1.5 billion in annual production for certain crops. Notably, some crops, such as tomatoes, blueberries, and cranberries, rely more on wild bees than honeybees due to their specialized pollination abilities. The decline of native bee species poses risks to various crops, impacting fruit yields.

As ongoing research and initiatives unfold, the comprehensive understanding of native bee populations and their habitats will be instrumental in implementing effective conservation strategies and ensuring the continued resilience of ecosystems and agricultural systems. Researchers stress the need to monitor native bees. Scientists lack data on species abundance, especially for solitary bees.

Honeybees, Bumblebees vs. Wild pollinators

Pollinators play a pivotal role in the reproduction of flowering plants, ensuring biodiversity and sustaining ecosystems. While honeybees and bumblebees are widely recognized for their pollination services, it is essential to acknowledge the often-overlooked importance of wild pollinators. In this section, we will emphasise the significance of wild pollinators and their unique contributions in comparison to honeybees and bumblebees.

Biodiversity Conservation

The preservation of wild pollinator species is crucial for overall biodiversity conservation. Many wild pollinators have specific relationships with native plants, and their decline can lead to cascading effects on other species within the ecosystem. Conservation efforts targeting wild pollinators contribute to the protection of entire ecosystems and the myriad species that depend on them.

Diversity of Wild Pollinators

Wild pollinators encompass a broad range of species, including various insects such as solitary bees, butterflies, moths, beetles, and even some species of flies. Unlike honeybees and bumblebees, which are managed and domesticated for agriculture, wild pollinators operate independently in natural ecosystems. The diversity of wild pollinators ensures resilience in pollination services across different environments.

Ecosystem Resilience

Wild pollinators contribute significantly to ecosystem resilience. Unlike honeybees, which primarily forage on a specific crop, wild pollinators have a more diverse foraging behavior. This diversity ensures the pollination of a wide variety of plants, promoting a balanced and resilient ecosystem. Wild pollinators are crucial for the reproduction of native plants, maintaining biodiversity, and supporting the intricate web of life within ecosystems.

Adaptation to Local Environments

Wild pollinators have evolved over time to adapt to local environments, forming specialized relationships with native plants. This adaptation is particularly important in regions where specific plant species depend on particular pollinators for successful reproduction. Unlike honeybees, which may not be native to certain areas, wild pollinators have co-evolved with local flora, making them essential for the preservation of indigenous plant species.

Pollination Efficiency

While honeybees are highly effective pollinators for certain crops, wild pollinators often exhibit equal or even superior efficiency in pollinating specific plants. Studies have shown that diverse pollinator communities increase crop yields and improve the quality of harvested produce. Wild pollinators exhibit varied foraging behaviors and preferences, enhancing the efficiency and effectiveness of pollination across different plant species.

Many wild pollinators have evolved specialized morphological and behavioral adaptations that enhance their pollination capabilities. For instance, the unique buzzing behavior of some solitary bees releases pollen more effectively than the vibration techniques employed by honeybees.

Climate Change Resilience

Wild pollinators may also exhibit greater resilience to climate change compared to honeybees and bumblebees. The ability of wild pollinator species to adapt to changing climates and shifting flowering patterns is crucial for maintaining pollination services in the face of global environmental challenges.

Balance between domestic and wild pollinators

Surprisingly, an increase in the number of honeybees and bumblebees, while seemingly beneficial for crop pollination, can have both positive and negative effects on wild pollinators and overall ecosystem dynamics. The impact depends on various factors, including the context of the ecosystem, the specific species involved, and the management practices employed. Here are some potential effects.

Positive Effects

Increased Crop Pollination

More honeybees and bumblebees can lead to increased pollination of crops, which is positive for agriculture. This may result in higher yields and improved quality of certain crops.

Economic Benefits

Increased honeybee populations can provide economic benefits for beekeepers engaged in managed pollination services. This can support the agricultural industry and contribute to local economies.

Pollinator Diversity in Agroecosystems

In some cases, managed honeybee colonies and bumblebee hives may enhance pollinator diversity in agricultural landscapes, especially where natural habitats are limited.

Negative Effects

Competition for Resources

The presence of large populations of honeybees and bumblebees can lead to increased competition for floral resources, potentially disadvantaging wild pollinators. This competition for nectar and pollen may impact the foraging success of smaller or less competitive species.

Disease Transmission

Honeybees and bumblebees can serve as vectors for diseases that may affect both managed and wild pollinators. Increased populations can potentially amplify the spread of diseases, posing a threat to the health of all bee species.

Altered Foraging Dynamics

The foraging behavior of honeybees and bumblebees can influence the behavior of wild pollinators. For example, honeybees are known to be efficient foragers and may deplete floral resources rapidly, leaving less for wild pollinators.

Genetic Pollution

In some cases, the introduction of large numbers of managed honeybee colonies, particularly non-native species, can lead to genetic pollution by potentially mating with and impacting the genetics of native bee populations.

Habitat Alterations

The management practices associated with large-scale honeybee pollination services, such as the transportation of colonies and concentrated foraging in specific areas, can lead to habitat alterations that may negatively impact local ecosystems.

It's important to note that the effects of increased honeybee and bumblebee populations can vary depending on the region, the specific crops involved, and the conservation practices implemented. Sustainable and ecosystem-based approaches to pollination management, including the conservation of natural habitats, promotion of diverse pollinator species, and careful consideration of the ecological context, are crucial for minimizing negative impacts and supporting overall pollinator health.

For example, the introduction of non-native bumblebee populations imported for pollination services in greenhouses, can pose risks to domestic (native) bumblebee populations and local ecosystems. When non-native bumblebee species are introduced to a new region, they may interact with native species in ways that can have negative ecological consequences.

Conclusion

While honeybees and bumblebees undeniably contribute significantly to agricultural pollination, it is crucial to recognize the indispensable role of wild pollinators in maintaining ecosystem health and biodiversity. Conservation efforts focused on protecting and promoting the habitats of wild pollinators are essential for ensuring the continued resilience of ecosystems worldwide. Recognizing and valuing the diverse contributions of wild pollinators is key to a sustainable and balanced approach to pollination in our ecosystems.

Different bee species exhibit varying degrees of efficiency in pollinating specific crops. Each crop may have specific requirements, and farmers may use a combination of managed and wild pollinators to optimize crop yields. Solitary bees, including various species of native bees, can be excellent pollinators for certain crops. These bees often exhibit specific adaptations that make them efficient pollinators for particular plants.

The availability and activity of pollinators vary across different seasons of the year and weather conditions. It's important to note that while certain pollinators may be more adaptable to specific weather conditions, a diverse community of pollinators is beneficial for ensuring reliable pollination services across a range of weather scenarios. The conservation and support of various pollinator species contribute to overall pollination resilience in changing weather conditions.

Methods of estimating bee abundance and richness in agroecosystems

Estimating bee abundance and richness in agroecosystems involves employing various methods that capture the diversity and population dynamics of bee species within agricultural landscapes.

Most commonly utilized methods

1) **Pan Traps** which consist of colored bowls filled with soapy water. Bees are attracted to the colors and fall into the liquid, allowing researchers to collect and identify them.
2) **Sweep Netting** used to collect bees from vegetation by sweeping the net through the plant canopy.
3) **Malaise Traps,** passive collection devices that intercept flying insects.
4) **Bee Bowls or Bee Vacs**.

Advanced methods

5) **DNA Barcoding**, a molecular technique that can be employed to identify bee species based on their genetic material.
6) **Remote Sensing**, advances in technology allow for the use of remote sensing tools, such as cameras and acoustic sensors, to monitor bee activity.
7) **Trap Nesting**, providing artificial nesting sites, such as bee hotels, allows researchers to study the nesting habits and diversity of solitary bees.

By employing a combination of these methods, researchers can gain a comprehensive understanding of bee abundance and richness in agroecosystems, contributing to the development of sustainable agricultural practices that support pollinator populations.

The "bee.directory" project focus

Main focus

A recent study reveals that, irrespective of the collection method employed, sampling durations typically do not exceed one hour and, at best, extend to a single day. Simultaneously, the number of sites visited for sampling purposes tends to fall within the range of 10-20, and the instances of sampling trips rarely exceed three.

Henceforth, the derived conclusions and recommendations are as follows:

1) Emphasizing a more intensive study of each site throughout the season holds greater significance than expanding the number of sites to optimize species diversity estimates. This approach enables the capture of diverse phenologies and species active at different times of the year.
2) Prioritizing research initiatives that span three or more years exerts a disproportionate impact on enhancing abundance estimates. Therefore, emphasis should be placed on conducting longer-term studies to maximize research outcomes.
3) In adherence to the standard practices of community ecology research, it is imperative that studies on bee communities not only report richness (total count of taxa found) but also address evenness, effective species number, and ideally, all three parameters.

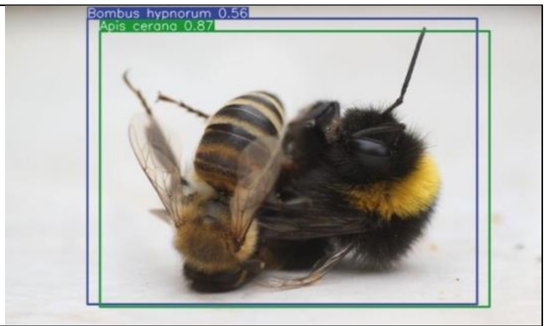
Inline with the above conclusions and recommendations, the "bee.directory" project will center on the integration of advanced techniques, specifically leveraging ***Remote Sensing*** and ***Trap Nesting***, complemented by the extensive application of **Machine Learning** and **Artificial Intelligence** methodologies.

While the primary objective of the project is to prioritize non-destructive methods, it will also offer support for *Pan traps* and *Malaise traps*. This support involves enabling the installation of satellite devices to facilitate data collection from the surrounding traps.

What about honey bees?

The project will encompass honey bee hive monitoring as well, deviating from the conventional emphasis on weight, honey gain/loss. Instead, it will place greater importance on monitoring parameters specific to pollination, such as bee counts, death rates, recognising main stressors, and nectar flow.

Simplified technical lansdcape

		
Bee hotels and other nesting sites outfitted with low-power-consuming IoT sensors designed to detect and record information on pollinator species, weather conditions, and geo-location.	A decentralized GPU-enabled node operating a YOLOv8 prediction model. Pairing collected species abundance and richness data with real time weather conditions and satellite imagery, and other available datasets (e.g. carbon-offset projects data, etc).	Realtime datasets comprising species predictions, counts, abundance and richness, and corresponding images. Timeseries and trends, analyzing temporal patterns and trends in conjunction with weather conditions and data from the surrounding environment and other complementing datasets.

Business models paradigm shift (read “ReFi”)

Business models within the current landscape of remote (honeybee hive) monitoring predominantly revolve around a singular stakeholder, namely the beekeeper. These models are largely centralized and typically hinge on either Hardware Sales and Installation or Subscription-based Services. However, beekeepers commonly exhibit hesitancy to invest in such systems and services, leading to limited market penetration. Consequently, even if the reliability of the collected data is guaranteed (and in many cases is not), its impact on conservation efforts remains constrained.

ReFi and the implementation of a fully decentralized network and marketplace, emerges as a promising solution to address this challenge. Enabling individuals to operate a node equipped with nesting site(s) infrastructure, and incentivizing their participation by contributing or selling generated datasets on a decentralized marketplace, creates a more inclusive model. Moreover, the opportunity for users to develop applications that leverage existing datasets on the marketplace to produce more valuable insights further enhances acceptance and engagement among interested parties.

Current state

Despite the author's sustained contemplation on the subject over the past few years and active involvement in various projects dedicated to combatting bee mortality and enhancing bee health, the current initiative is still in its nascent stage. The project is currently engaged in the early phases of planning, constructing the architecture, developing prototypes, and formulating predictive models.

Done so far:

1) First Yolov8 custom model is trained using open iNaturalist datasets. So far, the model is trained to predict / recognize following species.
    a) Apis cerana,
    b) Apis dorsata,
    c) Apis florea,
    d) Apis mellifera,
    e) Bombus auricomus,
    f) Bombus bimaculatus,
    g) Bombus borealis,
    h) Bombus californicus,
    i) Bombus citrinus,
    j) Bombus fervidus,
    k) Bombus flavifrons,
    l) Bombus griseocollis,
    m) Bombus huntii,
    n) Bombus hypnorum,
    o) Bombus impatiens,
    p) Bombus lapidarius.

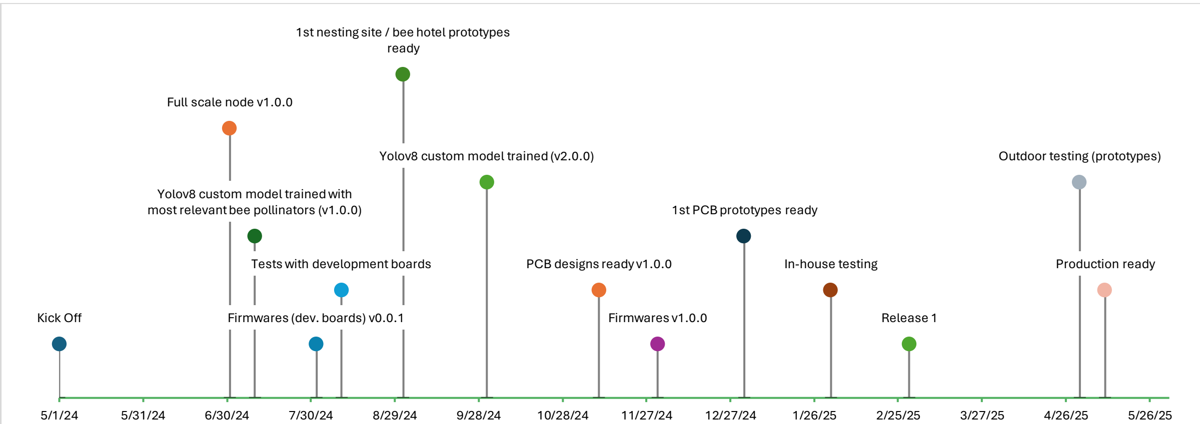
2) The ESP32 module, integrated with a camera, has been programmed and successfully tested against a trained model.

3) The foundational elements of the full scale node, built on libP2P, have been programmed to facilitate peering between nodes and operating a YOLOv8 prediction model. This includes the exchange of service catalogues containing information on available datasets and services.

4) A mini node prototype, utilizing the NVIDIA Jetson Nano Developer Kit, is in development for on-site operations. This compact node will be capable of running a YOLOv8 prediction model, particularly in locations where a reliable power supply is readily accessible.

5) The initiation of the development process for a desktop application, designed to facilitate the operation of a full-scale node on a personal computer, is underway.

Roadmap



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Disclamer

All illustrations in this document were generated with AI using Adobe Firefly.

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