US 20180065749A1

(19) **United States**

(12) **Patent Application Publication**

(10) **Pub. No.: US 2018/0065749 A1**

(43) **Pub. Date: Mar. 8, 2018**

Cantrell et al.

(54) **SYSTEMS AND METHODS FOR POLLINATING CROPS VIA UNMANNED VEHICLES**

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(21) Appl. No.: **15/697,106**

(22) Filed: **Sep. 6, 2017**

Related U.S. Application Data

(60) Provisional application No. 62/384,920, filed on Sep. 8, 2016.

Publication Classification

(51) **Int. Cl.**

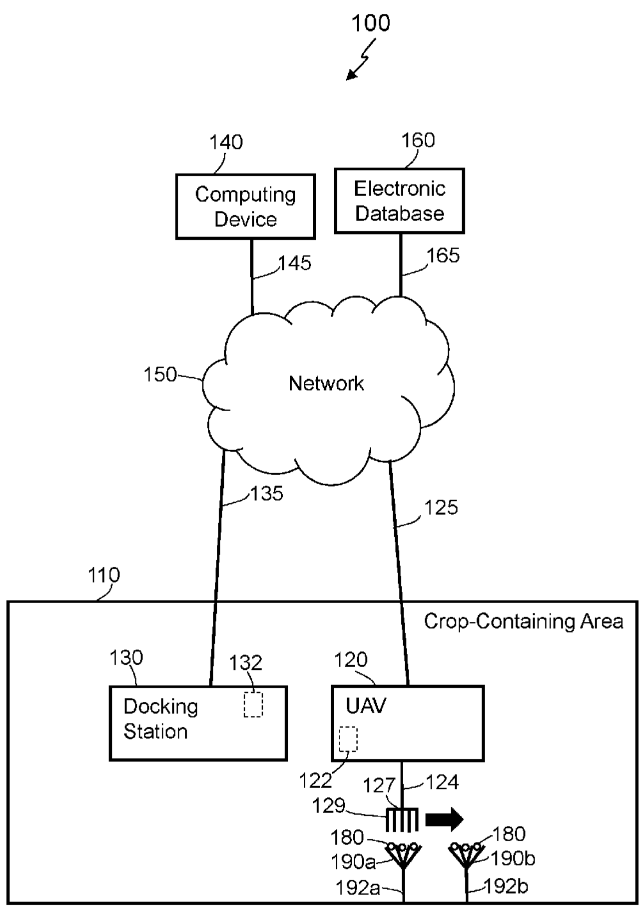
B64D 1/22	(2006.01)
A01G 1/00	(2006.01)
B64C 39/02	(2006.01)
G06K 9/00	(2006.01)
G06K 9/78	(2006.01)

(52) **U.S. Cl.**

CPC ***B64D 1/22*** (2013.01); ***A01G 1/001*** (2013.01); ***B64C 39/024*** (2013.01); *B64C 2201/146* (2013.01); ***G06K 9/78*** (2013.01); *B64C 2201/128* (2013.01); *B64C 2201/127* (2013.01); ***G06K 9/00657*** (2013.01)

(57) **ABSTRACT**

In some embodiments, methods and systems of pollinating crops include one or more unmanned vehicles including a pollen applicator configured to collect pollen from a flower of a first crop and to apply the pollen collected from the flower of the first crop onto a flower of a second crop and a sensor configured to detect presence of the pollen applied to the flower of the second crop by the pollen applicator to verify that the pollen collected from the flower of the first crop by the pollen applicator was successfully applied by the pollen applicator onto the flower of the second crop.



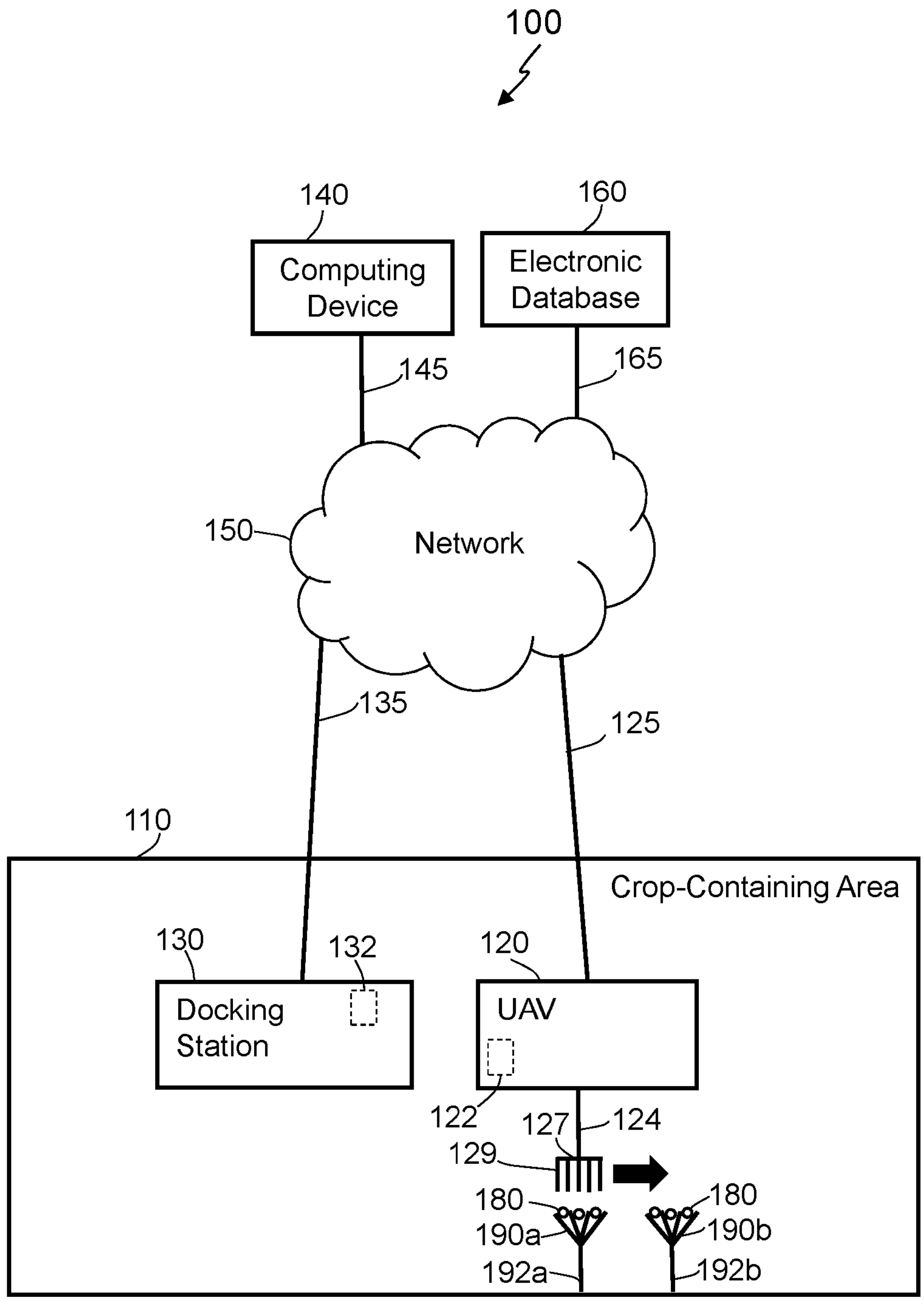

100
140
Computing Device
160
Electronic Database
145
165
150
Network
135
125
110
Crop-Containing Area
130
132
Docking Station
120
UAV
122
127
124
129
180
180
190a
190b
192a
192b

FIG. 1

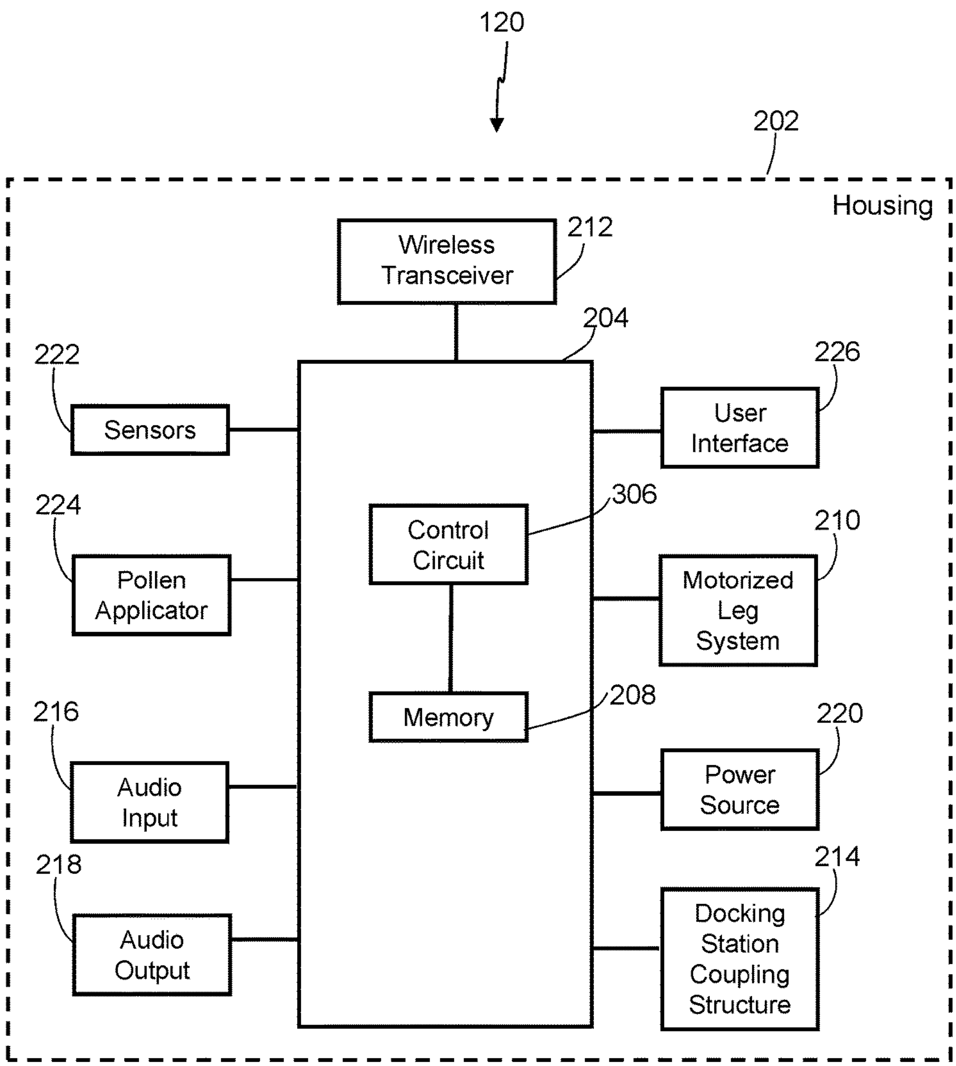

120
202
Housing
Wireless Transceiver
212
204
222
Sensors
226
User Interface
224
Pollen Applicator
Control Circuit
306
210
Motorized Leg System
Memory
208
216
Audio Input
220
Power Source
218
Audio Output
214
Docking Station Coupling Structure

FIG. 2

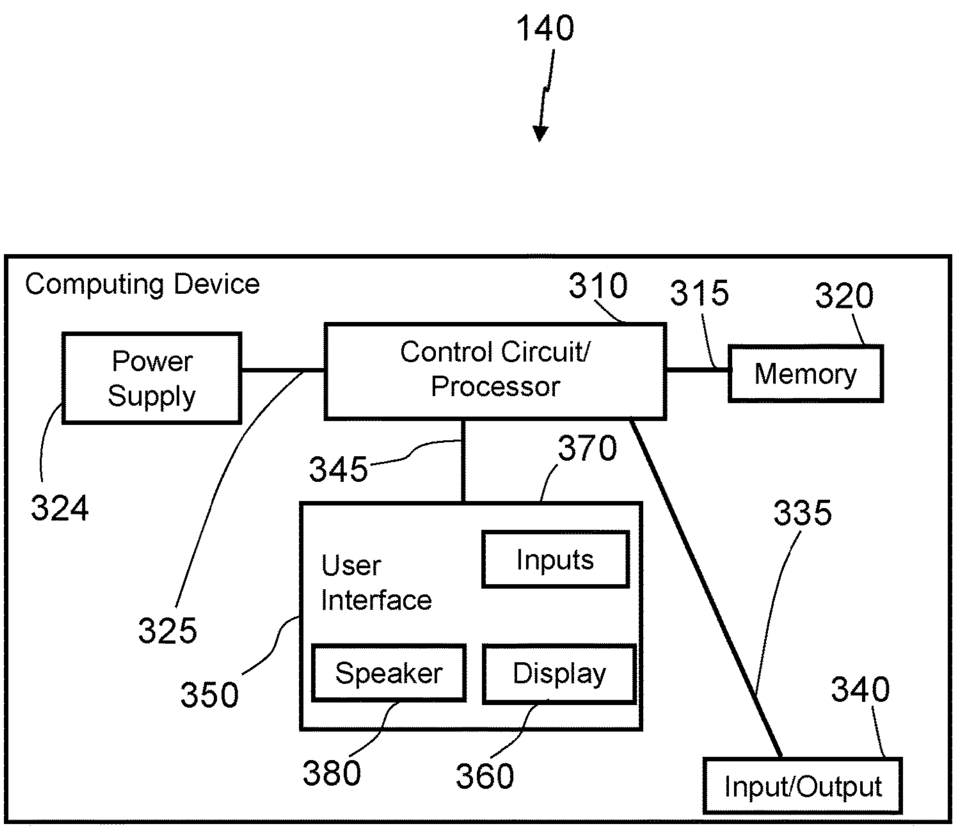

140
Computing Device
310
315
320
Power Supply
Control Circuit/ Processor
Memory
324
345
370
325
335
User Interface
Inputs
350
Speaker
Display
340
380
360
Input/Output

FIG. 3

400

410

providing at least one unmanned vehicle including:

- at least one pollen applicator configured to collect pollen from a flower of a first crop and to apply the pollen collected from the flower of the first crop onto a flower of a second crop; and
- at least one sensor configured to detect presence of the pollen applied to the flower of the second crop by the at least one pollen applicator to verify that the pollen collected from the flower of the first crop by the at least one pollen applicator was successfully applied by the at least one pollen applicator onto the flower of the second crop.

FIG. 4

SYSTEMS AND METHODS FOR POLLINATING CROPS VIA UNMANNED VEHICLES

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Application No. 62/384,920, filed Sep. 8, 2016, which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] This disclosure relates generally to pollinating crops, and in particular, to systems and methods for using unmanned vehicles to pollinate crops.

BACKGROUND

[0003] Since most flowering crops rely on insects and/or animals for pollination, pollinators are very important to the maintenance of both wild and agricultural plant communities. In recent years, the amount of pollinators (e.g., ants, bees, beetles, butterflies, wasps, etc.) has been in steady decline, which leads to reduced fertility and biodiversity of the crops and reduced crop production. While there have been attempts to fertilize crops by pollinating the crops via crop dusting, blanket spraying of pollen onto the crops from an airplane flying above ground is non-targeted and a significant percentage of the pollen may not reach its intended target crops due to the speed of the moving airplane and intervening wind. In an attempt to ensure that a large percentage of crops in the crop-containing area are pollinated, the crop-duster planes often spray more pollen than would be necessary then if the pollination were targeted, making crop duster-based pollination more expensive. In addition, since crop-dusters merely spray the pollen with the hope of providing maximum pollen coverage, but do not provide any verification of which crops were successfully pollinated and which were not, a significant percentage of crops may remain non-pollinated despite the excessive amount of pollen sprayed by the crop-duster.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Disclosed herein are embodiments of systems, devices, and methods pertaining to pollinating crops via unmanned vehicles. This description includes drawings, wherein:

[0005] FIG. **1** is a diagram of a system for pollinating crops via unmanned aerial vehicles (UAVs) in accordance with some embodiments;

[0006] FIG. **2** comprises a block diagram of a UAV as configured in accordance with various embodiments of these teachings;

[0007] FIG. **3** is a functional block diagram of a computing device in accordance with some embodiments; and

[0008] FIG. **4** is a flow diagram of a method of pollinating crops via UAVs in accordance with some embodiments.

[0009] Elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. For example, the dimensions and/or relative positioning of some of the elements in the figures may be exaggerated relative to other elements to help to improve understanding of various embodiments of the present invention. Also, common but well-understood elements that are useful or necessary in a commercially feasible embodiment are often not depicted in order to facilitate a less obstructed view of these various embodiments. Certain actions and/or steps may be described or depicted in a particular order of occurrence while those skilled in the art will understand that such specificity with respect to sequence is not actually required. The terms and expressions used herein have the ordinary technical meaning as is accorded to such terms and expressions by persons skilled in the technical field as set forth above except where different specific meanings have otherwise been set forth herein.

DETAILED DESCRIPTION

[0010] The following description is not to be taken in a limiting sense, but is made merely for the purpose of describing the general principles of exemplary embodiments. Reference throughout this specification to "one embodiment," "an embodiment," or similar language means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases "in one embodiment," "in an embodiment," and similar language throughout this specification may, but do not necessarily, all refer to the same embodiment.

[0011] Generally, the systems, devices, and methods for pollinating crops include one or more unmanned vehicles including at least one pollen applicator configured to collect pollen from a flower of a first crop and to apply the pollen collected from the flower of the first crop onto a flower of a second crop and a sensor configured to detect presence of the pollen applied to the flower of the second crop by the pollen applicator to verify that the pollen was successfully applied.

[0012] In one embodiment, a system for pollinating crops includes one or more unmanned vehicles including one or more pollen applicators configured to collect pollen from a flower of a first crop and to apply the pollen collected from the flower of the first crop onto a flower of a second crop and one or more sensors configured to detect presence of the pollen applied to the flower of the second crop by the pollen applicator to verify that the pollen collected from the flower of the first crop by the pollen applicator was successfully applied by the pollen applicator onto the flower of the second crop.

[0013] In another embodiment, a method of pollinating crops includes: providing one or more unmanned vehicles having one or more pollen applicators configured to collect pollen from a flower of a first crop and to apply the pollen collected from the flower of the first crop onto a flower of a second crop, and one or more sensors configured to detect presence of the pollen applied to the flower of the second crop by the pollen applicator to verify that the pollen collected from the flower of the first crop by the pollen applicator was successfully applied by the pollen applicator onto the flower of the second crop.

[0014] FIG. **1** illustrates an embodiment of a system **100** for dispensing pollen onto crops in a crop-containing area **110** and verifying that the crops were successfully pollinated with pollen. It will be understood that the details of this example are intended to serve in an illustrative capacity and are not necessarily intended to suggest any limitations in regards to the present teachings.

[0015] Generally, the exemplary system **100** of FIG. **1** includes a UAV **120** including one or more pollen applicators l **24** having a pollen applicator element **127** configured to collect pollen from a flower **190***a* of a first crop **192***a* and to apply the pollen collected from the flower **190***a* of the first crop **192***a* onto a flower **190***b* of a second crop **192***b*, and one or more sensors **122** configured to detect the presence of the pollen applied to the flower **190***b* of the second crop **192***b* by the pollen applicator element **127**, and to verify that the pollen collected from the flower **190***a* of the first crop **192***a* by the pollen applicator element **127** was successfully applied by the pollen applicator element **127** onto the flower **190***b* of the second crop **192***b*; a docking station **130** configured to permit the UAV **120** to land thereon and dock thereto to recharge; a processor-based computing device **140** in two-way communication with the UAV **120** (e.g., via communication channels **125** and **145**) and/or docking station **130** (e.g., via communication channels **135** and **145**) over the network **150**; and an electronic database **160** in two-way communication with at least the computing device **140** (e.g., via communication channels **145** and **165**) over the network **150**. It is understood that more or fewer of such components may be included in different embodiments of the system **100**.

[0016] As discussed above, while only one UAV **120** is shown in FIG. **1** for ease of illustration, it will be appreciated that in some embodiments, the computing device **140** may communicate with and/or provide flight route instructions and/or pollinating instructions to two or more UAVs **120** simultaneously to guide the UAVs **120** along their predetermined routes to pollinate the crops in the crop-containing area **110** and to detect the pollen applied by the pollen applicator **124** of the UAV **120** onto the crops. Similarly, while only one docking station **130** is shown in FIG. **1**, it will be appreciated that the system **100** may include two or more docking stations **130**, where the UAVs **120** may dock in order to recharge and/or to add or to other replace modular components of the UAV **120**. In some aspects, the computing device **140** and the electronic database **160** may be implemented as separate physical devices as shown in FIG. **1** (which may be at one physical location or two separate physical locations), or may be implemented as a single device. In some embodiments, the electronic database **160** may be stored, for example, on non-volatile storage media (e.g., a hard drive, flash drive, or removable optical disk) internal or external to the computing device **140**, or internal or external to computing devices distinct from the computing device **140**. In some embodiments, the electronic database **160** is cloud-based.

[0017] Generally, the UAV **120** is configured to fly above ground through a space overlying the crop-containing area **110**, to collect pollen **180** from a flower **190***a* of a first crop **192***a* and to apply the pollen **180** collected from the flower **190***a* of the first crop **192***a* onto a flower **190***b* of a second crop **192***b*, to detect the presence of the pollen **180** applied to the flower **190***b* of the second crop **192***b*, to land onto a docking station **130**, and to dock onto the docking station **130** (e.g., for recharging), as described in more detail below. While the docking station **130** is shown in FIG. **1** as being located in the crop-containing area **110**, it will be appreciated that one or more (or all) docking stations **130** may be positioned outside of the crop-containing area **110**. The docking station **130** may be configured as an immobile station or a mobile (e.g., vehicle mounted) station. In some embodiments, the docking station **130** is optional to the system **100** and, in such embodiments, the UAV **120** is configured to take off from a deployment station (e.g., stand-alone or vehicle mounted) to initiate the pollination of crops in the crop-containing area **110**, and to return to the deployment station without recharging after pollinating the crops.

[0018] In some embodiments, the UAV **120** deployed in the exemplary system **100** does not require physical operation by a human operator and wirelessly communicates with, and is wholly or largely controlled by, the computing device **140**. In particular, in some embodiments, the computing device **140** is configured to control directional movement and actions of the UAV **120** (e.g., flying, hovering, landing, taking off, moving while on the ground, pollinating the crops, detecting pollen **180** on the crops, etc.) based on a variety of inputs. Generally, the UAV **120** of FIG. **1** is configured to move around the crop-containing area **110** (e.g., above ground or on the ground), pollinate the flowers of the crops in the crop-containing area **110**, and detect the pollen **180** that was applied onto the flowers of the crops in the crop-containing area **110** via one or more sensors **122**.

[0019] While an unmanned aerial vehicle is generally described herein, in some embodiments, an aerial vehicle remotely controlled by a human may be utilized with the systems and methods described herein without departing from the spirit of the present disclosure. In some embodiments, the UAV **120** may be in the form of a multicopter, for example, a quadcopter, hexacopter, octocopter, or the like. In one aspect, the UAV **120** is an unmanned ground vehicle (UGV) that moves on the ground around the crop-containing area **110** under the guidance of the computing device **140** (or a human operator). In some embodiments, as described in more detail below, the UAV **120** includes a communication device (e.g., transceiver) configured to communicate with the computing device **140** while the UAV **120** is in flight and/or when the UAV **120** is docked at a docking station **130**.

[0020] As described above, the exemplary UAV **120** shown in FIG. **1** includes at least one sensor **122** configured to detect the presence of pollen **180** collected by the pollen applicator element **127** from a flower **190***a* of a first crop **192***a* and applied onto a flower **190***b* of a second crop **192***b* in the crop-containing area **110**. In some embodiments, the sensor **122** of the UAV **120** is configured to interpret the presence of the pollen **180** on the flower **190***b* of the second crop **192***b* in the crop-containing area **110** as a verification that the pollen **180** was successfully applied to the flower **190***b* of the second crop **192***b* by the UAV **120**. In some aspects, the sensor **122** is configured to merely detect the presence of the pollen **180** applied by the pollen applicator **124** onto the flower **190***b* of the second crop **192***b* and relay this detection data to another device (e.g., control circuit of the UAV **120**, control circuit of the computing device **140**, etc.) for interpreting this detection data as a verification that the pollen applicator **124** successfully applied the pollen **180** onto the flower **190***b* of the second crop **192***b*.

[0021] In some embodiments, the sensors **122** of the UAV **120** include a video camera configured to optically observe the flowers of the crops and/or the presence of pollen **180** applied onto the flowers of the crops by the pollen applicator **124**. In some embodiments, the video camera is a visible light camera, infrared camera, UV light camera, thermal camera, night-vision video camera, or the like cameras that are capable of providing a visual of the pollen **180** as it appears on the crops (e.g., on leaves, flowers, fruits, or stalks). The sensors **122** of the UAV **120** may be configured to detect pollen **180** on the crops during day or night pollination by the UAV **120**. In some aspects, the video camera is configured as a radar-type scanner that identifies surface areas on the crops where the pollen **180** is detected as hot spots.

[0022] In some aspects, the sensors **122** of the UAV **120** are configured to detect the presence of the pollen **180** applied by the pollen applicator element **127** on the crops (e.g., flowers, fruits, leaves, stalks, etc.) and to capture the presence of the pollen **180** on the crops as pollen detection data, which is then analyzed by the computing device **140** (or UAV **120**) to determine the coverage of the crops with pollen **180**. In some embodiments, after receiving pollen detection data indicating the detection of pollen **180** applied by the UAV **120** onto the crops in the crop-containing area **110** and determining that a high concentration of crops within a section of the crop-containing area **110** have flowers that were not successfully pollinated by the UAV **120**, the computing device **140** is configured to send a control signal to the UAV **120** to instruct the UAV **120** to further pollinate the crops in that section of the crop-containing area **110** via the pollen applicator element **127** (or a newly added modular applicator element).

[0023] In some embodiments, as described in more detail below, the sensors **122** of the UAV **120** include one or more docking station-associated sensors including but not limited to: an optical sensor, a camera, an RFID scanner, a short range radio frequency transceiver, etc. Generally, the docking station-associated sensors of the UAV **120** are configured to detect and/or identify the docking station **130** based on guidance systems and/or identifiers of the docking station **130**. For example, the docking station-associated sensor of the UAV **120** may be configured to capture identifying information of the docking station from one or more of a visual identifier, an optically readable code, a radio frequency identification (RFID) tag, an optical beacon, and a radio frequency beacon. In some embodiments, the sensors **122** of the UAV **120** may include other flight sensors such as optical sensors and radars for detecting obstacles (e.g., other UAVs **120**) to avoid collisions with such obstacles.

[0024] With reference to FIG. **1**, the pollen applicator **124** extends outwardly (e.g., downwardly) from the housing of the UAV **120** and is operatively coupled to a pollen applicator element **127** located externally to the housing of the UAV **120** and configured to collect pollen **180** from a flower **190***a* of a first crop **192***a* and apply the pollen **180** collected from the flower **190***a* of the first crop **192***a* onto a flower **190***b* of a second crop **192***b*. It will be appreciated that the pollen applicator **124** may be configured to collect pollen **180** from the flower **190***a* and either deposit the collected pollen **180** into a receptacle internal to the UAV **120** or otherwise securely retain the collected pollen **180** while the UAV **120** travels outside of the crop-containing area **110** to another crop-containing area, where the pollen **180** collected from the flower **190***a* can be applied onto and pollinate a flower of another crop of interest. In the embodiment of FIG. **1**, the exemplary pollen applicator element **127** is a brush-like structure including a plurality of bristles **129** configured for collecting, as the UAV **120** moves in a direction indicated by the directional arrow in FIG. **1**, pollen **180** from a flower **190***a* of a first crop **192***a* and to apply the pollen **180** collected from the flower **190***a* of the first crop **192***a* onto a flower **190***b* of a second crop **192***b*.

[0025] In some aspects, the bristles **129** are formed of at least one sticky material configured to cause the pollen **180** of the flower **190***a* of the first crop **192***a* to stick to the bristles **129** when the bristles are in contact with the pollen **180** of the flower **190***a* of the first crop **192***a*, and to permit the pollen **180** of the flower **190***a* of the first crop **192***a* stuck to the bristles **129** to be applied to the flower **190***b* of the second crop **192***b* when the bristles **129** come into contact with and/or are brushed against the flower **190***b* of the second crop **192***b*. Some suitable sticky materials from which the bristles **129** are formed in some embodiments include but are not limited to: acrylic oligomers, methacrylic oligomers, energy-curable acrylates, energy curable acrylic oligomers, tackifying resins, curable polymer/monomer combinations, aliphatic urethane acrylated oligomers, or the like.

[0026] In other aspects, instead of the bristles **129** themselves being formed of a sticky material, the external surfaces of the bristles **129** are coated with one or more sticky material configured to cause the pollen **180** of the flower **190***a* of the first crop **192***a* to stick to the sticky material coated on the bristles **129** when the bristles come into contact with the pollen **180** of the flower **190***a* of the first crop **192***a*, and to permit the pollen **180** of the flower **190***a* of the first crop **192***a* stuck to the sticky material coated on the bristles **129** to be applied to the flower **190***b* of the second crop **192***b* when the bristles **129** come into contact with and/or are brushed against the flower **190***b* of the second crop **192***b*. Some suitable sticky materials that may be coated onto the exterior surface of the bristles **129** in some embodiments include but are not limited to: acrylic oligomers, methacrylic oligomers, energy-curable acrylates, energy curable acrylic oligomers, tackifying resins, curable polymer/monomer combinations, aliphatic urethane acrylated oligomers, or the like.

[0027] In some embodiments, the bristles **129** are neither made of a sticky material, nor coated with a sticky material, but are made of a material having a non-sticky surface that is capable of lifting at least some of the pollen **180** off the flower **190***a* of the first crop **192***a*, retaining the pollen while the UAV **120** carries the bristles **129** toward the flower **190***b* of the second crop **192***b*, and releasing at least some of the pollen **180** onto the flower **190***b* of the second crop **192***b* from the bristles **129** when the bristles **129** are brought into contact with the flower **190***b*, or are shaken over the flower **190***b* of the second crop **192***b*.

[0028] In some embodiments, the pollen applicator **124** is operatively coupled to a pollen applicator element **127** configured to collect the pollen **180** of the flower **190***a* of the first crop **192***a* without the bristles **129** of the pollen applicator element **127** being in direct contact with the pollen **180** of the flower **190***a* of the first crop **192***a*, and to apply the pollen **180** collected from the flower **190***a* of the first crop **192***a* to the flower **190***b* of the second crop **192***b* without the bristles **129** of the pollen applicator element **127** being in direct contact with the flower **190***b* of the second crop **192***b*. For example, in some aspects, as the UAV **120** flies over the flower **190***a* of the first crop **192***a* with the pollen applicator **124** extending downwardly from the UAV **120** in a direction toward the flower **190***a* of the first crop **192***a*, the velocity of movement of the bristles **129** in close proximity to the flower **190***a* of the first crop **192***a* may create sufficient air flow to cause at least some of the pollen **180** present on the flower **190***a* of the first crop **192***a* to lift up and stick to the bristles **129**, which may be either formed of sticky material or coated with a sticky material as discussed above. By the same token, as the UAV **120** flies over the flower **190***b* of the second crop **192***b* with the pollen applicator **124** extending downwardly from the UAV **120** in a direction toward the flower **190***b* of the second crop **192***b* and the bristles **129** of the pollen applicator element **127** of the pollen applicator **124** carrying the pollen **180** picked up from the flower **190***a* of the first crop **192***a*, the velocity of movement of the bristles **129** in close proximity to the flower **190***b* of the second crop **192***b* may create sufficient air flow to cause at least some of the pollen **180** stuck to the bristles **129** to fall off the bristles **129** and onto the flower **190***b* of the second crop **192***b* (as generally shown in FIG. **1**), thereby pollinating the flower **190***b* of the second crop **192***b*.

[0029] In some aspects, the UAV **120** includes at least one sensor **122** configured to measure the speed and direction of wind in the crop-containing area **110** and capture such wind detection data. Such wind detection data can facilitate the control circuit of the computing component **140** (or the control circuit of the UAV **120**) to determine where the UAV **120** should be moved in order to position the pollen-containing bristles **129** in an optimal location for being carried by the pre-measured and pre-analyzed wind toward and onto the flowers in the crop-containing area **110** desired to be pollinated by this pollen **180**. As such, in some embodiments, the detection of speed and direction of wind via one or more sensors **122** advantageously facilitates a higher efficacy application of pollen **180** to one or more flowers of interest without requiring the UAV **120** to bring the pollen-containing bristles **129** into direct contact with such flowers.

[0030] In some embodiments, the pollen applicator element **127** is operatively coupled to an air flow generating component (e.g., a hose, rotor, spray nozzle, etc.) configured to generate air flow sufficient to cause the pollen **180** collected from the flower **190***a* of the first crop **192***a* by the bristles **129** to be blown off the bristles **129** and directed toward the flower **190***b* of the second crop **192***b*. As such, the pollen **180** collected by the bristles **129** from the flower **190***a* of the first crop can be applied onto the flower **190***b* of the second crop **192***b* without the bristles **129** of the pollen applicator element **127** having to come into direct contact with the flower **190***b* of the second crop **192***b*. In one aspect, the air flow generating component blows the pollen **180** off the bristles **129** to pollinate not only the flower **190***b* of the second crop **192***b*, but other flowers adjacent the flower **190***b*. Thus, the lifting of pollen **180** from one or more flowers in the crop-containing area **110** via the bristles **129** of the pollen applicator element **127** of the UAV **120**, when followed by the use of an air-flow generating component to blow the pollen **180** off the bristles **129** and in a direction of one or more other flowers in the crop-containing area **110** advantageously creates one or more air streams carrying a higher concentration of the pollen **180** of interest than would be naturally blown by the wind off the individual flowers in the crop-containing area **110**.

[0031] In some embodiments, at least one sensor **122** of the UAV **120** is configured to detect and measure the concentration of pollen present in the crop-containing area **110**, or in individual sections of the crop-containing area **110**. It will be appreciated that in some embodiments, one or more of the docking stations **130** may also include one or more such pollen-detecting sensors **122**. In one aspect, a pollen-detecting sensor measures the concentration of pollen **180** (i.e., the pollen of interest for pollinating the flower **190***b*) present in the air.

[0032] In some embodiments, the pollen detection data obtained by the pollen-detecting sensor is analyzed by a control circuit of the UAV **120** or a control circuit of the computing device **140** to determine whether the concentration of pollen **180** needs to be increased in the air in order to increase the likelihood that the pollen **180** (i.e., the pollen of interest for pollination purposes) is successfully propagated by air from the flower **190***a* to the flower **190***b* via the above-described air-generating component. Similarly, the pollen detection data obtained by the pollen-detecting sensor is analyzed by a control circuit of the UAV **120** or a control circuit of the computing device **140** to determine whether the concentration of a random, inferior pollen needs to be decreased in the air in order to increase the likelihood that the pollen **180** (i.e., the pollen of interest for pollination purposes) is successfully propagated by air from the flower **190***a* to the flower **190***b* via the above-described air-generating component or naturally-occurring wind.

[0033] For example, a control circuit of the UAV **120** and/or the control circuit of the computing device **120** can be programmed to determine that increasing the concentration of the pollen **180** (i.e., a cross-pollinating pollen of interest) in the air will significantly increase the probability that the pollen **180** (and not some random wind-borne pollen) will pollinate the flower **190***b* of the second crop **192***b*. In one aspect, responsive to such a determination, the air-generating component of the pollen applicator **124** can be caused (via a control signal sent by the control circuit of the UAV **120** of the control circuit of the computing device) to increase the concentration of the pollen **180** in the air (e.g., by moving some pollen via the bristles **129** and/or increasing air flow in a desired direction near flowers that produce the pollen of interest for pollinating the target flowers of interest). As such, pollen-detecting sensors **122** can enable the efficiency of the UAV **120** in increasing the probability that pollen from a desired crop is delivered to the crop desired to be pollinated preferentially to all other inferior pollens that may be present in the air in the crop-containing area **110**.

[0034] In some embodiments, the pollen applicator **124** includes one or more detasseling component configured to remove the pollen-producing flowers or tassel from some of the crops in the crop-containing area **110**. In one aspect, the detasseling component of the pollen applicator **124** includes one or more cutting elements configured to remove the tassel or flower **190***b* from the second crop **192***b* when such cutting elements come into contact with the pollen-producing flower **190***b* of the second crop **192***b* during movement of the UAV **120**. In some aspects, the first and second crops **192***a* and **192***b* are of different varieties and, after the flower **190***b* of the second crop **192***b* is removed (e.g., clipped off via the detasseling component such that the flower **190***b* simply falls onto the ground), the pollen applicator **124** of the UAV **120** can advantageously cross-pollinate the seeds of the second crop **192***b* with pollen **180** from the flower **190***a* of the first crop **192***a* as described above (e.g., via lifting the pollen off the flower **190***a* using sticky bristles **192** and/or using an air generating component that can stream the pollen **180** onto the second crop **192***b*.

[0035] In some embodiments, instead of being a brush-like structure including bristles **129**, the pollen applicator element **127** is an air flow generating device (e.g., a hose, rotor, spray nozzle, etc.) configured to generate air flow sufficient to cause the pollen **180** present on the flower **190***a* of the first crop **192***a* to be blown off the surface of the flower **190***a* and directed toward the flower **190***b* of the second crop **192***b*. As such, the pollen **180** present on the surface of the flower **190***a* of the first crop **192***a* can be applied to the flower **190***b* of the second crop **192***b* without any portion of the pollen applicator element **127** coming into direct contact with the pollen **180** on the flower **190***a*. In one aspect, the pollen **180** that is blown off the flower **190***a* by the air flow generating device of the pollen applicator element **127** can advantageously pollinates not only the flower **190***b* of the second crop **192***b*, but also flowers located adjacent the flower **190***b* in the crop-containing area **110**.

[0036] In some embodiments, instead of being a brush-like structure including bristles **129**, the pollen applicator element **127** is a spreader, a pad, a cloth, or the like element configured to collect pollen **180** from a flower **190***a* of a first crop **192***a* and apply the pollen **180** collected from the flower **190***a* of the first crop **192***a* onto a flower **190***b* of a second crop **192***b*. Examples of some other suitable pollen applicator arms are discussed in co-pending application entitled "SYSTEMS AND METHODS FOR DISPENSING POLLEN ONTO CROPS VIA UNMANNED VEHICLES," filed Sep. 8, 2016, which is incorporated by reference herein in its entirety.

[0037] In some embodiments, the pollen applicator **124** is configured to be lowered from the housing of the UAV **120**, for example, via an aerial crane. In some aspects, an aerial crane may be any device configured to move the pollen applicator **124** between a retracted position that is closer to the housing of the UAV **120** and a deployed position that is further away from the housing of the UAV **120**. For example, in some embodiments, an aerial crane may comprise one or more pulleys and extendable cables coupled to the pollen applicator **124** via, for example, one or more of a hook, a latch, a clamp, a clip, a magnet, etc. In some embodiments, the aerial crane may be configured to unwind the cable to lower the pollen applicator **124** toward the crops while the UAV **120** maintains a hover altitude (e.g. **5-10** feet above the crops). In some embodiments, the aerial crane may be configured to at least partially retract the cable into the housing of the aerial crane before the UAV **120** flies from one location in the crop-containing area **110** to another, or while the UAV **120** attempts to land onto or dock to a docking station **130**. In some embodiments, the aerial crane may be controlled by a control circuit of the UAV **120**. In some embodiments, the aerial crane may comprise a separate control circuit activated by the computing device **140** and/or a wireless transmitter of the docking station **130**.

[0038] FIG. **2** presents a more detailed example of the structure of the UAV **120** of FIG. **1** according to some embodiments. The exemplary UAV **120** of FIG. **2** has a housing **202** that contains (partially or fully) or at least supports and carries a number of components. These components include a control unit **204** comprising a control circuit **206** that, like the control circuit **310** of the computing device **140**, controls the general operations of the UAV **120**. For example, in some embodiments, the control circuit **310** of the computing device **140** may determine an optimal timing of pollination of the crops **192***a*, **192***b* with the pollen **180** via the UAV **120** in view of other possible seasonal sources of pollen and unintended cross-contamination. The control circuit **206** can comprise a fixed-purpose hard-wired platform or can comprise a partially or wholly programmable platform. These architectural options are well known and understood in the art and require no further description.

[0039] The control circuit **206** is configured (e.g., by using corresponding programming stored in the memory **208** as will be well understood by those skilled in the art) to carry out one or more of the steps, actions, and/or functions described herein. The memory **208** may be integral to the control circuit **206** or can be physically discrete (in whole or in part) from the control circuit **206** as desired. This memory **208** can also be local with respect to the control circuit **206** (where, for example, both share a common circuit board, chassis, power supply, and/or housing) or can be partially or wholly remote with respect to the control circuit **206**. The memory **208** can serve, for example, to non-transitorily store the computer instructions that, when executed by the control circuit **206**, cause the control circuit **206** to behave as described herein. It is noted that not all components illustrated in FIG. **2** are included in all embodiments of the UAV **120**. That is, some components may be optional depending on the implementation.

[0040] The control unit **204** of the UAV **120** of FIG. **2** includes a memory **208** coupled to the control circuit **206** for storing data (e.g., pollen detection data, instructions sent to the UAV **120** by the computing device **140**, or the like). As discussed above, in some embodiments, the UAV **120** is not dependent on the electronic database **160** for storing pollen detection data and on the computing device **140** for determining, based on the pollen detection data, whether the pollen **180** picked up by the pollen applicator **124** of the UAV **120** from the flower **190***a* of the first crop **192***a* was successfully applied to the flower **190***b* of the second crop **192***b*, and then sending a control signal to the UAV **120** whether or not to apply additional pollen to the flower **190***b* of the second crop **192***b*. Instead, in some aspects, the memory **208** of the UAV **120** is configured to store pollen detection data and the control circuit **206** of the UAV **120** is programmed to analyze the pollen detection data captured by the sensors **122** of the UAV **120**, and determine, based on the pollen detection data, whether the pollen **180** picked up by the pollen applicator **124** of the UAV **120** from the flower **190***a* of the first crop **192***a* was successfully applied to the flower **190***b* of the second crop **192***b*, and then send a control signal to the pollen applicator **124** whether or not to apply additional pollen **180** to the flower **190***b* of the second crop **192***b*. For example, in some embodiments, the control circuit **206** of the UAV **120** is programmed to determine (e.g., by analyzing the pollen detection data captured by the sensor **122**) that the pollen applied to the flower **190***b* of the second crop **192***b* was not successfully applied onto the crops, for example, due to wind or rain interference, and to send a control signal to the pollen applicator **124** to apply additional pollen **180** onto the flower **190***b* of the second crop **192***b* accordingly.

[0041] In some embodiments, the control circuit **206** of the UAV **120** operably couples to a motorized leg system **210**. This motorized leg system **210** functions as a locomotion system to permit the UAV **120** to land onto the docking station **130** and/or move while on the docking station **130**. Various examples of motorized leg systems are known in the art. Further elaboration in these regards is not provided here for the sake of brevity save to note that the aforementioned control circuit **206** may be configured to control the various operating states of the motorized leg system **210** to thereby control when and how the motorized leg system **210** operates.

[0042] In the exemplary embodiment of FIG. **2**, the control circuit **206** operably couples to at least one wireless transceiver **212** that operates according to any known wireless protocol. This wireless transceiver **212** can comprise, for example, a cellular-compatible, Wi-Fi-compatible, and/or Bluetooth-compatible transceiver that can wirelessly communicate with the computing device **140** via the network **150**. So configured, the control circuit **206** of the UAV **120** can provide information to the computing device **140** (via the network **150**), and can receive information and/or movement and/or pollinating instructions from the computing device **140**.

[0043] For example, the wireless transceiver **212** may be caused (e.g., by the control circuit **206**) to transmit to the computing device **140**, via the network **150**, at least one signal indicating pollen detection data captured by a pollen-detecting sensor **122** of the UAV **120** while hovering over the crop-containing area **110**. In some embodiments, the control circuit **206** receives instructions from the computing device **140** via the network **150** to apply additional pollen (e.g., to flower **190***b* of the second crop **192***b*) via the pollen applicator **124**. In one aspect, the wireless transceiver **212** is caused (e.g., by the control circuit **206**) to transmit an alert to the computing device **140**, or to another computing device (e.g., hand-held device of a worker at the crop-containing area **110**) indicating that one or more flowers of one or more crops in the crop-containing area **110** were not successfully pollinated by the pollen applicator **124** of the UAV **120**. These teachings will accommodate using any of a wide variety of wireless technologies as desired and/or as may be appropriate in a given application setting. These teachings will also accommodate employing two or more different wireless transceivers **212**, if desired.

[0044] The control circuit **206** also couples to one or more on-board sensors **222** of the UAV **120**. These teachings will accommodate a wide variety of sensor technologies and form factors. As discussed above, the on-board sensors **222** of the UAV **120** can include sensors including but not limited to one or more sensors configured to detect the presence and/or location of pollen on the flowers (e.g., **190***a*, **190***b*) of the crops (**192***a*, **192***b*), as well as on the ground adjacent to the crops **192***a*, **192***b* in the crop-containing area **110**, as well as the concentration of pollen **180** (and different types of pollen) in the air. Such sensors **222** can provide information (e.g., pollen detection data) that the control circuit **206** of the UAV **120** and/or the control circuit of the computing device **140** can analyze to determine whether the pollen applicator **124** of the UAV **120** successfully applied the pollen **180** to the flower **190***b* of the second crop **192***b*. For example, in some embodiments, the UAV **120** includes an on-board sensor **222** in the form of a video camera configured to detect the presence of the pollen **180** on the flower **190***b* of the second crop **192***b* and capture video-based pollen detection data that enables a visual confirmation of the presence of the pollen **180** on the flower **190***b* of the second crop **192***b*.

[0045] In some embodiments, the sensors **222** of the UAV **120** are configured to detect objects and/or obstacles (e.g., other UAVs **120**, docking stations **130**, birds, animals, etc.) along the path of travel of the UAV **120**. In some embodiments, using on-board sensors **222** (such as distance measurement units, e.g., laser or other optical-based distance measurement sensors), the UAV **120** may attempt to avoid obstacles, and if unable to avoid, the UAV **120** will stop until the obstacle is clear and/or notify the computing device **140** of such a condition.

[0046] By one optional approach, an audio input **216** (such as a microphone) and/or an audio output **218** (such as a speaker) can also operably couple to the control circuit **206** of the UAV **120**. So configured, the control circuit **206** can provide for a variety of audible sounds to enable the UAV **120** to communicate with the docking station **130** or other UAVs **120**. Such sounds can include any of a variety of tones and other non-verbal sounds.

[0047] In the embodiment of FIG. **2**, the UAV **120** includes a rechargeable power source **220** such as one or more batteries. The power provided by the rechargeable power source **220** can be made available to whichever components of the UAV **120** require electrical energy. By one approach, the UAV **120** includes a plug or other electrically conductive interface that the control circuit **206** can utilize to automatically connect to an external source of electrical energy (e.g., charging dock **132** of the docking station **130**) to recharge the rechargeable power source **220**. By one approach, the UAV **120** may include one or more solar charging panels to prolong the flight time (or on-the-ground driving time) of the UAV **120**.

[0048] These teachings will also accommodate optionally selectively and temporarily coupling the UAV **120** to the docking station **130**. In such embodiments, the UAV **120** includes a docking station coupling structure **214**. In one aspect, a docking station coupling structure **214** operably couples to the control circuit **206** to thereby permit the latter to control movement of the UAV **120** (e.g., via hovering and/or via the motorized leg system **210**) towards a particular docking station **130** until the docking station coupling structure **214** can engage the docking station **130** to thereby temporarily physically couple the UAV **120** to the docking station **130**. So coupled, the UAV **120** can recharge via a charging dock **132** of the docking station **130**.

[0049] In some embodiments, the UAV **120** includes a pollen applicator **224** coupled to the control circuit **206**. Generally, the pollen applicator **224** is configured to dispense pollen onto the crops in the crop-containing area **110**. As discussed in more detail above with reference to the embodiment of FIG. **1**, an exemplary pollen applicator **224** may include a brush-like pollen applicator element **127** that includes bristles **129** (e.g., formed of a sticky, pollen adhering material or coated with a sticky, pollen-adhering material) configured to collect pollen **180** from a flower **190***a* of a first crop **192***a* and to apply the pollen **180** collected from the flower **190***a* of the first crop **192***a* onto a flower **190***b* of a second crop **192***b*. In some embodiments, the bristles **129** are made of a light and flexible material (e.g., rubber, polyethylene, or the like).

[0050] In some embodiments, the UAV **120** includes a user interface **226** including for example, user inputs and/or user outputs or displays depending on the intended interaction with a user (e.g., operator of computing device **140**) for purposes of, for example, manual control of the UAV **120**, or diagnostics, or maintenance of the UAV **120**. Some exemplary user inputs include but are not limited to input devices such as buttons, knobs, switches, touch sensitive surfaces, display screens, and the like. Example user outputs include lights, display screens, and the like. The user interface **226** may work together with or separate from any user interface implemented at an optional user interface unit (e.g., smart phone or tablet) usable by an operator to remotely access the UAV **120**. For example, in some embodiments, the UAV **120** may be controlled by a user in direct proximity to the UAV **120** (e.g., a worker at the crop-containing area **110**). This is due to the architecture of some embodiments where the computing device **140** outputs the control signals to the UAV **120**. These controls signals can originate at any electronic device in communication with the computing device **140**. For example, the movement signals sent to the UAV **120** may be movement instructions determined by the computing device **140** and/or initially transmitted by a device of a user to the computing device **140** and in turn transmitted from the computing device **140** to the UAV **120**.

[0051] A docking station **130** of FIG. **1** is generally a device configured to permit at least one or more UAVs **120** to dock thereto. The docking station **130** may be configured as an immobile station (i.e., not intended to be movable) or as a mobile station (intended to be movable on its own, e.g., via guidance from the computing device **140**, or movable by way of being mounted on or coupled to a moving vehicle), and may be located in the crop-containing area **110**, or outside of the crop-containing area **110**. For example, in some aspects, the docking station **130** may receive instructions from the computing device **140** over the network **150** to move into a position on a predetermined route of a UAV **120** over the crop-containing area **110**.

[0052] In one aspect, the docking station **130** includes at least one charging dock **132** that enables at least one UAV **120** to connect thereto and charge. In some embodiments, a UAV **120** may couple to a charging dock **132** of a docking station **130** while being supported by at least one support surface of the docking station **130**. In one aspect, a support surface of the docking station **130** may include one or more of a padded layer and a foam layer configured to reduce the force of impact associated with the landing of a UAV **120** onto the support surface of the docking station **130**. In some embodiments, a docking station **130** may include lights and/or guidance inputs recognizable by the sensors of the UAV **120** when located in the vicinity of the docking station **130**. In some embodiments, the docking station **130** may also include one or more coupling structures configured to permit the UAV **120** to detachably couple to the docking station **130** while being coupled to a charging dock **132** of the docking station **130**.

[0053] In some embodiments, the docking station **130** is configured (e.g., by including a wireless transceiver) to send a signal over the network **150** to the computing device **140** to, for example, indicate if one or more charging docks **132** of the docking station **130** are available to accommodate one or more UAVs **120**. In one aspect, the docking station **130** is configured to send a signal over the network **150** to the computing device **140** to indicate a number of charging docks **132** on the docking station **130** available for UAVs **120**. The control circuit **310** of the computing device **140** is programmed to guide the UAV **120** to a docking station **130** moved into position along the predetermined route of the UAV **120** and having an available charging dock **132**.

[0054] In some embodiments, a docking station **130** may include lights and/or guidance inputs recognizable by the sensors of the UAV **120** when located in the vicinity of the docking station **130**. In some aspects, the docking station **130** and the UAV **120** are configured to communicate with one another via the network **150** (e.g., via their respective wireless transceivers) to facilitate the landing of the UAV **120** onto the docking station **130**. In other aspects, the transceiver of the docking station **130** enables the docking station **130** to communicate, via the network **150**, with other docking stations **130** positioned at the crop-containing area **110**.

[0055] In some embodiments, the docking station **130** may also include one or more coupling structures configured to permit the UAV **120** to detachably couple to the docking station **130** while being coupled to a charging dock **132** of the docking station **130**. In one aspect, the UAV **120** is configured to transmit signals to and receive signals from the computing device **140** over the network **150** only when docked at the docking station **130**. For example, in some embodiments, after the pollen detection data captured by the sensors **122** of the UAV **120** is transmitted over the network **150** to the computing device **140** and the computing device **140** analyzes the pollen detection data to verify the presence of pollen **180** applied by the UAV **120** on the flower **190*b*** of the second crop **192*b***, the UAV **120** is configured to receive a signal from the computing device **140** (containing instructions indicating whether the UAV **120** is to attempt to apply additional pollen **180** onto the flower **190*b*** of the second crop **192*b***) only when the UAV **120** is docked at the docking station **130**. In other embodiments, the UAV **120** is configured to communicate with the computing device **140** and receive a signal from the computing device **140** (containing instructions indicating whether the UAV **120** is to attempt to apply additional pollen **180** onto the flower **190*b*** of the second crop **192*b***) while the UAV **120** is not docked at the docking station **130**.

[0056] In some embodiments, the docking station **130** may be configured to not only recharge the UAV **120**, but also to re-equip the pollen applicator **124** of the UAV **120**, and/or to add modular components to the pollen applicator **124** of the UAV **120**. For example, in some embodiments, the docking station **130** is configured to provide for addition of new modular components to the pollen applicator **124** of the UAV **120** (e.g., the above-discussed pollen applicator element **127** and/or bristles **129** may be coupled to the pollen applicator **124** or uncoupled from the pollen applicator **124** at the docking station **130**.

[0057] In some embodiments, the docking station **130** may itself be equipped with a pollen applicator **124** akin to the pollen applicator **124** of the UAV **120** to enable the docking station **130** to collect pollen **180** from the flower **190*a*** of the first crop **192*a*** and apply the pollen **180** to the flower **190*b*** of the second crop **192*b***. As such, in some aspects of the system **100**, the pollen **180** can be applied to the flower **190*b*** of the second crop **192*b*** not only by the UAV **120**, but also by the docking station **130**, thereby advantageously increasing the pollinating capabilities of the system **100**.

[0058] In some embodiments, the docking station **130** is configured to provide for the addition of new modular components to the UAV **120** to enable the UAV **120** to better interact with the operating environment where the crop-containing area **110** is located. For example, in some aspects, the docking station **130** is configured to enable the coupling of various types of landing gear to the UAV **120** to optimize the ground interaction of the UAV **120** with the docking station **130** and/or to optimize the ability of the UAV **120** to land on the ground in the crop-containing area **110**. In some embodiments, the docking station **130** is configured to enable the coupling of new modular components (e.g., rafts, pontoons, sails, or the like) to the UAV **120** to enable the UAV **120** to land on and/or move on wet surfaces and/or water. In some embodiments, the docking station **130** may be configured to enable modifications of the visual appearance of the UAV **120**, for example, via coupling, to the exterior body of the UAV **120**, one or more modular components (e.g., wings) designed to, for example, prolong the flight time of the UAV **120**. It will be appreciated that the relative sizes and proportions of the docking station **130** and UAV **120** in FIG. **1** are not drawn to scale.

[0059] The computing device **140** of the exemplary system **100** of FIG. **1** may be a stationary or portable electronic device, for example, a desktop computer, a laptop computer, a tablet, a mobile phone, or any other electronic device. In some embodiments, the computing device **140** may comprise a control circuit, a central processing unit, a processor, a microprocessor, and the like, and may be one or more of a server, a computing system including more than one computing device, a retail computer system, a cloud-based computer system, and the like. Generally, the computing device **140** may be any processor-based device configured to communicate with the UAV **120**, docking station **130**, and electronic database **160** in order to guide the UAV **120** as it moves above ground or on the ground at the crop-containing area **110** and/or docks to a docking station **130** (e.g., to recharge) and/or deploys from the docking station **130** and/or picks up the pollen **180** from the flower **190***a* of the first crop **192***a* and/or applies the pollen **180** onto the flower **190***b* of the second crop **192***b*.

[0060] The computing device **140** may include a processor configured to execute computer readable instructions stored on a computer readable storage memory. The computing device **140** may generally be configured to cause the UAVs **120** to: travel (e.g., fly, hover, or drive) around the crop-containing area **110**, along a route determined by a control circuit of the computing device **140**; detect the docking station **130** positioned along the route predetermined by the computing device **140**; land on and/or dock to the docking station **130**; undock from and/or lift off the docking station **130**; pollinate crops **192***a*, **192***b* in the crop-containing area **110** via the pollen applicator **124**, and detect the presence of the pollen **180** dispensed by the pollen applicator **124** on the crops **192***a*, **192***b*. In some embodiments, the electronic database **160** includes pollen detection data captured by the sensors **122** of the UAV **120** and transmitted to the electronic database **160** by the UAV **120** (e.g., via the computing device **140**), and the computing device **140** is configured to analyze such pollen detection data and interpret the presence of pollen **180** dispensed via the pollen applicator **124** on the crops **192***a*, **192***b* as a verification that the pollen **180** dispensed by the UAV **120** was successfully applied to the crops **192***a*, **192***b*, and to instruct the UAV **120** to dispense additional pollen **180** onto the crops, if the pollen verification data indicates that crops **192***a*, **192***b* in one or more sections of the crop-containing area **110** were not successfully pollinated. In such embodiments, the pollen detection data is stored remotely to the UAV **120** and the determination of whether the pollen **180** dispensed by the UAV **120** was successfully applied to the crops **192***a*, **192***b* is made remotely to the UAV **120**, namely, at the computing device **140**, thereby reducing the data storage and processing power requirements of the UAV **120**.

[0061] With reference to FIG. **3**, a computing device **140** according to some embodiments configured for use with exemplary systems and methods described herein may include a control circuit **310** including a processor (e.g., a microprocessor or a microcontroller) electrically coupled via a connection **315** to a memory **320** and via a connection **325** to a power supply **330**. The control circuit **310** can comprise a fixed-purpose hard-wired platform or can comprise a partially or wholly programmable platform, such as a microcontroller, an application specification integrated circuit, a field programmable gate array, and so on. These architectural options are well known and understood in the art and require no further description here.

[0062] The control circuit **310** can be configured (for example, by using corresponding programming stored in the memory **320** as will be well understood by those skilled in the art) to carry out one or more of the steps, actions, and/or functions described herein. In some embodiments, the memory **320** may be integral to the processor-based control circuit **310** or can be physically discrete (in whole or in part) from the control circuit **310** and is configured non-transitorily store the computer instructions that, when executed by the control circuit **310**, cause the control circuit **310** to behave as described herein. (As used herein, this reference to "non-transitorily" will be understood to refer to a non-ephemeral state for the stored contents (and hence excludes when the stored contents merely constitute signals or waves) rather than volatility of the storage media itself and hence includes both non-volatile memory (such as read-only memory (ROM)) as well as volatile memory (such as an erasable programmable read-only memory (EPROM))). Accordingly, the memory and/or the control circuit may be referred to as a non-transitory medium or non-transitory computer readable medium.

[0063] In some embodiments, the control circuit **310** of the computing device **140** is programmed to, in response to receipt (via the network **150**) of pollen detection data (captured by the sensor **122** of the UAV **120**) from the UAV **120**, cause the computing device **140** to analyze such pollen detection data. In some aspects, the control circuit **310** of the computing device **140** is configured to transmit, over the network **150**, the pollen detection data received from the UAV **120** to the electronic database **160**, such that the electronic database **160** can be updated in real time to include up-to-date pollen detection information in the crop-containing area **110**. In one aspect, the computing device **140** is configured to access, via the network **150**, the pollen detection data stored on the electronic database **160** to determine whether the pollen **180** dispensed by the UAV **120** onto the flower **190***b* of the second crop **192***b* is actually present on the flower **190***b* of the second crop **192***b* as initially intended.

[0064] In some embodiments, the control circuit **310** of the computing device **140** is programmed to generate a control signal to the UAV **120** based on a determination of whether the pollen detection data indicates that the targeted flower **190***b* of the second crop **192***b* was successfully pollinated by the pollen **180** dispensed by the UAV **120** or not. For example, such a control signal may instruct the UAV **120** to move toward a section of the crop-containing area **110** containing one or more crops having flowers that were determined by the control circuit **310** of the computing device **140** as not having been successfully pollinated by the pollen **180** dispensed by the UAV **120**, and to dispense additional pollen **180** over that section of the crop-containing area **110** in order to successfully pollinate the flowers of the crops in that section. In some aspects, the control circuit **310** is programmed to cause the computing device **140** to transmit such control signal to the UAV **120** over the network **150**.

[0065] The control circuit **310** of the computing device **140** is also electrically coupled via a connection **335** to an input/output **340** (e.g., wireless interface) that can receive wired or wireless signals from one or more UAVs **120**. Also, the input/output **340** of the computing device **140** can send signals to the UAV **120**, such as signals including instructions whether or not to attempt to apply additional pollen **180** to the flower **190***b* of the second crop **192***b*, or which docking station **130** the UAV **120** is to land on for recharging while hovering over the crop-containing area **110** along a route predetermined by the computing device **140**.

[0066] In the embodiment shown in FIG. **3**, the processor-based control circuit **310** of the computing device **140** is electrically coupled via a connection **345** to a user interface **350**, which may include a visual display or display screen **360** (e.g., LED screen) and/or button input **370** that provide the user interface **350** with the ability to permit an operator of the computing device **140**, to manually control the computing device **140** by inputting commands via touch-screen and/or button operation and/or voice commands to, for example, to send a signal to the UAV **120** in order to, for example: control directional movement of the UAV **120** while the UAV **120** is moving along a (flight or ground) route (over or on the crop-containing area **110**) predetermined by the computing device **140**; control movement of the UAV **120** while the UAV **120** is landing onto a docking station **130**; control movement of the UAV **120** while the UAV is lifting off a docking station **130**; control movement of the UAV **120** while the UAV **120** is in the process of collecting pollen **180** from the flower **190***a* of the first crop **192***a* or applying the pollen **180** onto the flower **190***b* of the second crop **192***b*; and/or control the movement of the UAV **120** while the UAV **120** attempts to detect whether the pollen **180** was successfully applied by the pollen applicator **124** onto the flower **190***b* of the second crop **192***b*. Notably, the performance of such functions by the processor-based control circuit **310** of the computing device **140** is not dependent on actions of a human operator, and that the control circuit **310** may be programmed to perform such functions without being actively controlled by a human operator.

[0067] In some embodiments, the display screen **360** of the computing device **140** is configured to display various graphical interface-based menus, options, and/or alerts that may be transmitted from and/or to the computing device **140** in connection with various aspects of movement of the UAV **120** in the crop-containing area **110** as well as with various aspects of pollination of plants by the pollen applicator **124** of the UAV **120** in response to the instructions received from the computing device **140**. The inputs **370** of the computing device **140** may be configured to permit a human operator to navigate through the on-screen menus on the computing device **140** and make changes and/or updates to the routes of the UAV **120**, application of pollen **180** to one or more flowers **190***a*, **190***b* of one or more crops **192***a*, **192***b* in the crop-containing area **110** via the pollen applicator **124**, and/or the locations of the docking stations **130**. It will be appreciated that the display screen **360** may be configured as both a display screen and an input **370** (e.g., a touch-screen that permits an operator to press on the display screen **360** to enter text and/or execute commands.) In some embodiments, the inputs **370** of the user interface **350** of the computing device **140** may permit an operator to, for example, manually configure instructions to the UAV **120** for applying additional pollen **180** to the flower **190***b* of the second crop **192***b*.

[0068] In some embodiments, the computing device **140** automatically generates a travel route for the UAV **120** from its deployment station to the crop-containing area **110**, and to or from the docking station **130** while moving over or on the crop-containing area **110**. In some embodiments, this route is based on a starting location of a UAV **120** (e.g., location of deployment station) and the intended destination of the UAV **120** (e.g., location of the crop-containing area **110**, and/or location of docking stations **130** in or around the crop-containing area **110**).

[0069] As discussed above, the electronic database **160** of FIG. **1** is configured to store electronic data including, but not limited to: pollen detection data captured by the sensors **122** of the UAV **120** after application of pollen **180** onto the flower **190***b* of the second crop **192***b*; data indicating location of the UAV **120** (e.g., GPS coordinates, etc.); data indicating locations within the crop-containing area **110** where additional pollen **180** was applied by the UAV **120**; route of the UAV **120** when moving from a deployment station to the crop-containing area **110**, while flying over the crop-containing area **110**, or when returning from the crop-containing area **110** to the deployment station; data indicating communication signals and/or messages sent between the computing device **140**, UAV **120**, electronic database **160**, and/or docking station **130**; data indicating location (e.g., GPS coordinates, etc.) of the docking station **130**; and/or data indicating identity of one or more UAVs **120** docked at each docking station **130**. As discussed above, in some embodiments, such electronic data is stored in the memory **208** of the UAV **120**, such that the control circuit **206** of the UAV **120** accesses such electronic data from the memory **208** of the UAV **120** without having to access a remote electronic database over the network **150**.

[0070] In some embodiments, location inputs are provided via the network **150** to the computing device **140** to enable the computing device **140** to determine the location of one or more of the UAVs **120** and/or one or more docking stations **130**. For example, in some embodiments, the UAV **120** and/or docking station **130** may include a GPS tracking device that permits a GPS-based identification of the location of the UAV **120** and/or docking station **130** by the computing device **140** via the network **150**. In one aspect, the computing device **140** is configured to track the location of the UAV **120** and docking station **130**, and to determine, via the control circuit **310**, an optimal route for the UAV **120** from its deployment station to the crop-containing area **110** and/or an optimal docking station **130** for the UAV **120** to dock to while traveling along its predetermined route. In some embodiments, the control circuit **310** of the computing device **140** is programmed to cause the computing device **140** to communicate such tracking and/or routing data to the electronic database **160** for storage and/or later retrieval.

[0071] In view of the above description referring to FIGS. **1-3**, and with reference to FIG. **4**, a method **400** of pollinating crops in a crop-containing area **110** according to some embodiments will now be described. While the process **400** is discussed as it applies to dispensing pollen **180** onto the flower **190**_b_ of the second crop **192**_b_ in the crop-containing area **110** and detecting the presence of the dispensed pollen **180** on the flower **190**_b_ of the second crop **192**_b_ and interpreting the presence of the pollen **180** on the flower **190**_b_ of the second crop **192**_b_ as a verification that the dispensed pollen **180** was successfully applied to the flower **190**_b_ of the second crop **192**_b_ via the exemplary system **100** shown in FIG. **1**, it will be appreciated that the process **400** may be utilized in connection with any of the embodiments described herein.

[0072] The exemplary method **400** depicted in FIG. **4** includes providing one or more UAVs **120** including at least one pollen applicator element **127** configured to collect pollen **180** from a flower **190**_a_ of a first crop **192**_a_ and to apply the pollen **180** collected from the flower **190**_a_ of the first crop **192**_a_ onto a flower **190**_b_ of a second crop **190**_b_; and at least one sensor **122** configured to detect presence of the pollen **180** applied to the flower **190**_b_ of the second crop **192**_b_ by the pollen applicator element **127** to verify that the pollen **180** collected from the flower **190**_a_ of the first crop **192**_a_ by the pollen applicator **124** was successfully applied by the pollen applicator **124** onto the flower **190**_b_ of the second crop **192**_b_ (step **410**).

[0073] As discussed above in more detail, in some embodiments, the method **400** further includes collecting the pollen **180** from the flower **190**_a_ of the first crop **192**_a_ and applying the pollen **180** onto the flower **190**_b_ of the second crop **192**_b_ via a pollen applicator element **127** including sticky bristles **129** and, in some embodiments, the method **400** includes collecting the pollen **180** from the flower **190**_a_ of the first crop **192**_a_ and applying the pollen **180** onto the flower **190**_b_ of the second crop **192**_b_ via a pollen applicator element **127** including one of a spreader, a pad, a cloth, a spray gun, or the like.

[0074] In some aspects, the method **400** further includes detecting the presence of the pollen **180** applied by the bristles **129** of the pollen applicator element **127** of the pollen applicator **127** onto the flower **190**_b_ of the second crop **192**_b_ via one or more sensors **122** of the UAV **120**. As discussed above in more detail, in some embodiments, the sensors **122** of the UAV **120** include a camera capable of capturing pollen detection data that provides an optical-based, chemical-based, or heat/temperature-based indication of the pollen **180** as it appears on the flower **190**_b_ of the second crop **192**_b_. In some embodiments, this pollen detection data is then analyzed (e.g., by the computing device **140** or by the UAV **120**) in order to determine how successfully the pollen **180** was applied to the flower **190**_b_ of the second crop **192**_b_. In some embodiments, after collection, by the UAV **120**, of pollen detection data indicating the detection of pollen **180** applied by the UAV **120** onto the flower **190**_b_ of the second crop **192**_b_, and after a determination by the computing device **140** as to whether additional pollen **180** needs to be applied onto the flower **190**_b_ of the second crop **192**_b_, the method further includes sending a control signal to the UAV **120** over the network **150** from the computing device **140** to instruct the UAV **120** to apply additional pollen to the flower **190**_b_ of the second crop **192**_b_ after a determination by the computing device that the flower **190**_b_ of the second crop **192**_b_ was not successfully pollinated when the pollen **180** was initially dispensed.

[0075] The systems and methods described herein advantageously provide for semi-automated or fully automated targeted pollination of the flowers of crops in crop-containing areas via unmanned vehicles and detecting whether the dispensed pollen was successfully applied onto the flowers of the crops intended to be pollinated. As such, the present systems and methods significantly reduce the amount of pollen that needs to be dispensed and significantly reduce the resources needed to determine whether the pollen was successfully applied onto the flowers of the crops, thereby, thereby advantageously providing an efficient, self-sufficient, and cost-effective pollination system.

[0076] Those skilled in the art will recognize that a wide variety of other modifications, alterations, and combinations can also be made with respect to the above described embodiments without departing from the scope of the invention, and that such modifications, alterations, and combinations are to be viewed as being within the ambit of the inventive concept.

What is claimed is:

1. A system for pollinating crops, the system comprising:
at least one unmanned vehicle including:
at least one pollen applicator configured to collect pollen from a flower of a first crop and to apply the pollen collected from the flower of the first crop onto a flower of a second crop; and
at least one sensor configured to detect presence of the pollen applied to the flower of the second crop by the at least one pollen applicator to verify that the pollen collected from the flower of the first crop by the at least one pollen applicator was successfully applied by the at least one pollen applicator onto the flower of the second crop.

2. The system of claim **1**, wherein the at least one sensor of the at least one unmanned vehicle includes a video camera configured to optically observe the flower of the second crop to detect the presence of the pollen applied by the at least one pollen applicator onto the flower of the second crop.

3. The system of claim **1**, wherein the at least one unmanned vehicle includes a body and the pollen applicator includes at least one arm extending outwardly from the body, and wherein the at least one arm is operatively coupled to at least one of: a spreader, a pad, a cloth, and a brush configured to collect the pollen from the flower of the first crop and to apply the pollen collected from the flower of the first crop onto the flower of the second crop.

4. The system of claim **3**, wherein the brush includes a plurality of bristles formed of at least one sticky material configured to cause the pollen of the flower of the first crop to stick to the bristles when the bristles are in contact with the pollen of the flower of the first crop and to permit the pollen of the flower of the first crop stuck to the bristles to be applied to the flower of the second crop when the bristles are in contact with the flower of the second crop.

5. The system of claim **3**, wherein the brush includes a plurality of bristles coated with at least one sticky material configured to cause the pollen of the flower of the first crop to stick to the bristles when the bristles are in contact with the pollen of the flower of the first crop and to permit the pollen of the flower of the first crop stuck to the bristles to be applied to the flower of the second crop when the bristles are in contact with the flower of the second crop.

6. The system of claim **3**, wherein the at least one arm is operatively coupled to at least one pollen dispenser configured to collect the pollen of the flower of the first crop without being in direct contact with the pollen of the flower of the first crop and to apply the pollen collected by the at least one pollen dispenser from the flower of the first crop to the flower of the second crop without being in direct contact with the flower of the second crop.

7. The system of claim **1**, wherein the at least one unmanned vehicle is one of an unmanned aerial vehicle and an autonomous ground vehicle.

8. The system of claim **1**, further comprising:

at least one docking station positioned proximate at least one of the first and second crop and configured to accommodate the at least one unmanned vehicle; and

a computing device including a processor-based control circuit and configured to communicate with the at least one unmanned vehicle and the at least one docking station via a wireless network.

9. The system of claim **8**, wherein the at least one unmanned vehicle is configured to send a signal over the wireless network to the computing device via the wireless network, the signal including pollen detection data captured by the at least one sensor of the at least one unmanned vehicle upon detection of the presence of the pollen applied by the at least one pollen applicator on the flower of the second crop, and wherein the control circuit of the computing device is programmed to control movement of the at least one unmanned vehicle over the wireless network based on the signal received at the computing device from the at least one unmanned vehicle.

10. The system of claim **9**, further comprising an electronic database in communication with at least one of the computing device and the at least one unmanned vehicle, the electronic database configured to store the pollen detection data received over the wireless network by the computing device from the at least one unmanned vehicle.

11. A method of pollinating crops, the method comprising:

providing at least one unmanned vehicle including:

at least one pollen applicator configured to collect pollen from a flower of a first crop and to apply the pollen collected from the flower of the first crop onto a flower of a second crop; and

at least one sensor configured to detect presence of the pollen applied to the flower of the second crop by the at least one pollen applicator to verify that the pollen collected from the flower of the first crop by the at least one pollen applicator was successfully applied by the at least one pollen applicator onto the flower of the second crop.

12. The method of claim **11**, wherein the providing step further comprises providing the at least one sensor with a video camera configured to optically observe the flower of the second crop to detect the presence of the pollen applied by the at least one pollen applicator onto the flower of the second crop.

13. The method of claim **11**, wherein the providing step further comprises providing the at least one unmanned vehicle having a body and at least one arm extending outwardly from the body, the at least one arm being operatively coupled to at least one of: a spreader, a pad, a cloth, and a brush configured to collect the pollen from the flower of the first crop and to apply the pollen collected from the flower of the first crop onto the flower of the second crop.

14. The method of claim **13**, further comprising providing the brush with a plurality of bristles formed of at least one sticky material configured to cause the pollen of the flower of the first crop to stick to the bristles when the bristles are in contact with the pollen of the flower of the first crop and to permit the pollen of the flower of the first crop stuck to the bristles to be applied to the flower of the second crop when the bristles are in contact with the flower of the second crop.

15. The method of claim **13**, further comprising providing the brush with a plurality of bristles coated with at least one sticky material configured to cause the pollen of the flower of the first crop to stick to the bristles when the bristles are in contact with the pollen of the flower of the first crop and to permit the pollen of the flower of the first crop stuck to the bristles to be applied to the flower of the second crop when the bristles are in contact with the flower of the second crop.

16. The method of claim **13**, further comprising operatively coupling the at least one arm to at least one pollen dispenser configured to collect the pollen of the flower of the first crop without being in direct contact with the pollen of the flower of the first crop and to apply the pollen collected by the at least one pollen dispenser from the flower of the first crop to the flower of the second crop without being in direct contact with the flower of the second crop.

17. The method of claim **11**, wherein the providing step further comprises providing at least the at least one unmanned vehicle in a form of one of an unmanned aerial vehicle and an autonomous ground vehicle.

18. The method of claim **11**, further comprising:

providing at least one docking station positioned proximate at least one of the first and second crop and configured to accommodate the at least one unmanned vehicle; and

providing a computing device including a processor-based control circuit and configured to communicate with the at least one unmanned vehicle and the at least one docking station via a wireless network.

19. The method of claim **18**, further comprising:

transmitting, from the at least one unmanned vehicle and over the wireless network, a signal to the computing device, the signal including pollen detection data captured by the at least one sensor of the at least one unmanned vehicle upon detection of the presence of the pollen applied by the at least one pollen applicator on the flower of the second crop; and

controlling, via the control circuit of the computing device and over the wireless network, movement of the at least one unmanned vehicle based on the signal received at the computing device from the at least one unmanned vehicle.

20. The method of claim **19**, further comprising:

providing an electronic database in communication with at least one of the computing device and the at least one unmanned vehicle; and

storing, on the electronic database, the pollen detection data received over the wireless network by the computing device from the at least one unmanned vehicle.

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