



(43) International Publication Date
13 October 2016 (13.10.2016)

- (51) International Patent Classification:
B64C 25/32 (2006.01) *B64C 25/40* (2006.01)
B64C 25/34 (2006.01)
- (21) International Application Number:
PCT/US2016/026152
- (22) International Filing Date:
6 April 2016 (06.04.2016)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
62/143,605 6 April 2015 (06.04.2015) US
- (71) Applicant: ARCHON TECHNOLOGIES S.R.L. [IT/IT];
Incubatore Modena Hub R-Nord, Strada Attiraglio 1A-1B,
41123 Modena (IT).
- (72) Inventor; and
- (71) Applicant (for US only): VENTURELLI, Davide
[IT/US]; 100 Van Ness Avenue, San Francisco, CA 94102
(US).
- (72) Inventor: LORENZONI, Francesca; c/o Archon Techno-
logies S.R.L., Via Vittorio Bachelet, 4, 41057 Spilamberto
Modena (IT).

(74) Agents: PACELLI, Andrea et al.; Wilmer Culter Picker-
ing Hale and Dorr LLP, 7 World Trade Center, 250 Green-
wich Street, New York, NY 10007 (US).

(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY,
BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM,
DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,
HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR,
KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG,
MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM,
PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC,
SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ,
TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU,
TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE,
DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU,
LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,
SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ,
GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: GROUND MOVEMENT SYSTEM PLUGIN FOR VERTICAL TAKE OFF AND LANDING UNMANNED AERIAL VEHICLES

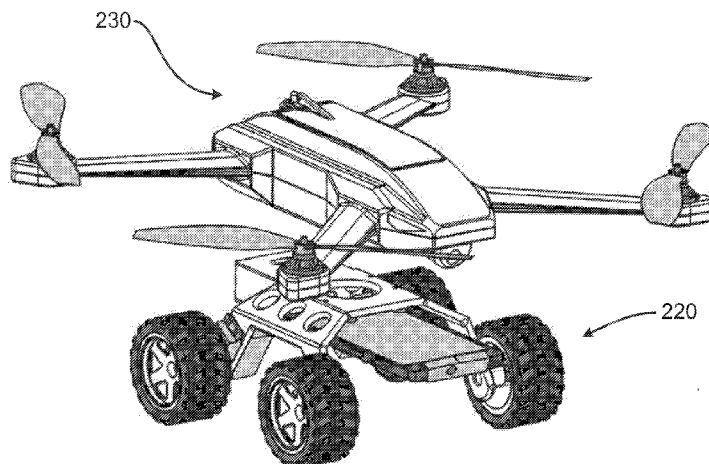


FIG. 2

(57) Abstract: A ground movement plug-in (GMP) apparatus for providing ground propulsion to an unmanned aircraft vehicle (UAV). In an embodiment, the GMP apparatus includes a frame configured to mechanically couple with the UAV, a plurality of wheels, at least one of which is actuatable by a motor, and a controller operably coupled to the motor to control propulsion of the GMP apparatus.



Ground Movement System Plugin for Vertical Take Off and Landing Unmanned Aerial Vehicles

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims benefit of the earlier filing date of U.S. Provisional Patent Application No.: 62/143,605, titled “Motorized Ground Propulsion System Plugin for Vertical Take Off and Landing Unmanned Aerial Vehicles,” filed on April 6, 2015, the entire contents of which are hereby incorporated by reference in their entirety.

[0002] All patents, patent applications and publications cited herein are hereby incorporated by reference in their entirety in order to more fully describe the state of the art as known to those skilled therein as of the date of the invention described herein.

FIELD OF THE INVENTION

[0003] One or more embodiments of the present disclosure generally relate to autonomous landing operations of an unmanned aerial vehicle (UAV) or “drone.” More specifically, one or more embodiments relate to ground propulsion systems for UAVs.

BACKGROUND

[0004] Small helicopters and multi-copters, including hybrid airplanes with vertical take-off and landing (VTOL) vehicles, are a fast expanding technology in the civil market. They are increasingly used in operations that expose people to risk (e.g., in chemical plants, nuclear plants, etc.), activities carried out in highly inaccessible areas (e.g., viaducts, skyscrapers, furnaces, offshore rescue, etc.), and monitoring procedures requiring a high degree of precision (e.g., inspection of cracks in dams/bridges, airplane maintenance, oil tank keels, etc.).

In addition to industrial and governmental critical infrastructure applications, potential applications of VTOL vehicle technology range from industrial (e.g., in plants, machineries, etc.) to environmental safeguarding (e.g., volcanoes, parks, coasts, etc.), including the protection of sensitive areas (e.g., archaeological sites, territorial borders, etc.). However, most vehicles available on the market have a limited range (e.g., 15 to 25 minutes of flight time, depending on the typology of their mission), which limits the possibility of a wider deployment of this technology.

SUMMARY OF THE INVENTION

[0005] Embodiments set forth herein include a pluggable hardware extension, or ground movement plug-in (GMP), that is attachable to a vertical take-off and landing (VTOL) unmanned aerial vehicle (UAV), such as a multicopter. The GMP (or “GMP vehicle”) can be configured to attach to and/or move the UAV, for example on the ground, with or without directional constraints. In addition or alternatively, the GMP can be configured to physically support a smooth landing of the UAV. The GMP can reposition an attached UAV to a predetermined position that is accessible, for example, via ground movement. The predetermined position can be a compartment of a docking station, for example, for recharging, package or “payload” delivery, data downloading, etc.

[0006] In some embodiments, a GMP includes: a frame configured to mechanically couple with the UAV, a plurality of wheels, at least one wheel of the plurality of wheels actuatable by a motor; and a controller operably coupled to the motor to control propulsion of the apparatus. The frame can include an adapter to mechanically and/or electrically couple to the UAV and/or to any one of a plurality of UAV types/sizes.

[0007] In some embodiments, a UAV is able to reach a specific location, for example a docking station and/or charger, regardless of imprecise landing, adverse weather conditions or other mitigating factors, such as low visibility. In other words, once a UAV is attached to a GMP, it can acquire the properties and capabilities of a rover robot.

[0008] In some embodiments, an apparatus for providing ground propulsion to a UAV includes a frame configured to mechanically couple with the UAV, a plurality of wheels, at least one of which is actuatable by a motor, and a controller operably coupled to the motor to control propulsion of the apparatus. The controller can be adapted to interface, during use, with at least one of an electronic board of the UAV and a remote control unit. The frame of the apparatus can be configured to mechanically and electrically couple to a computer. The apparatus can also include a charger, such as a wireless charger, configured to connect to and recharge a battery of the UAV during use. The apparatus can be electrically coupled to the UAV, for example, when at least a portion of the UAV is received in or on the apparatus (e.g., after the UAV has landed on the apparatus).

[0009] In some embodiments, the apparatus receives electrical power from a power supply of the UAV instead of, or in addition to, a local or onboard power supply.

[0010] In some embodiments, the apparatus includes a battery.

[0011] In some embodiments, the apparatus includes at least one of: a GPS receiver, an antenna, and a gimbal.

[0012] In some embodiments, the apparatus includes a computer operably coupled to the controller, the computer including a processor and a non-transitory memory storing processor-issuable instructions to drive the motor. The computer can include a camera configured to capture at least one of video and still images and, optionally, an image processor to process the at least one of video and still images. The computer can also include an antenna configured to communicate with a remote terminal, such as the UAV or a docking station.

[0013] In some embodiments, the apparatus includes a sensor to receive position data, the GPS receiver operably coupled to the controller, the non-transitory memory storing processor-issuable instructions to drive the motor to reposition the vehicle based on the position data. The sensor can include one or more of: a GPS receiver, an accelerometer, a gyroscope, LIDAR, or a visual recognition system. Position data collected by the sensor during use can include position data of the GMP vehicle and/or position data of a UAV.

[0014] In some embodiments, a system includes a UAV and an apparatus for providing ground propulsion to the UAV. The apparatus includes a frame configured to mechanically couple with the UAV, a plurality of wheels, at least one of which is actuatable by a motor, and a controller operably coupled to the motor to control propulsion of the apparatus.

[0015] In some embodiments, a method for providing ground propulsion to a UAV includes coupling the UAV to a propulsion apparatus and controlling the propulsion apparatus using the controller to propel the UAV. The propulsion apparatus can include a frame configured to mechanically couple with the UAV, a plurality of wheels, at least one wheel of which is actuatable by a motor, and a controller operably coupled to the motor to control propulsion of the apparatus, and

[0016] In some embodiments, an apparatus for providing ground propulsion to an unmanned aircraft vehicle (UAV) includes: a propulsion device including at least one of a continuous track and one or more mechanical leg(s) for propulsion; and a frame configured to mechanically couple with the UAV. The propulsion device can be configured to actuate, during use, in response to an externally applied force such as wind or a motor of the UAV. In some such embodiments, the apparatus includes the UAV.

[0017] In some embodiments, a system includes a UAV and an apparatus for providing ground propulsion to the UAV. The apparatus includes a propulsion device including at least one of a continuous track and a mechanical leg; and a frame configured to mechanically couple with the UAV.

[0018] In some embodiments, the apparatus for providing ground propulsion to the UAV is a GMP.

[0019] The GMP can be configured such that it is removably attachable to the UAV, or it can be configured such that it becomes permanently attached to the UAV once engaged therewith. The GMP can be designed to be attached on a top, bottom or side surface of the UAV, and can include an attachment comprising one or more of: clamps, screws, tapes, glue interfaces, straps, elastic material, ropes, wires, magnetostatic systems, electromagnetic systems, and/or any other system by which the GMP can be mechanically and/or electrically coupled to the UAV. The attachment procedure can include skilled integration work, or can be performed quickly (e.g., in a matter of seconds) without modifying the UAV airframe. The UAV can comprise a multicopter, a helicopter, or any unmanned aircraft of any size which is capable of VTOL.

[0020] In some embodiments, the GMP system can be installed on a UAV via a mechanical joint. Alternatively or in addition, the GMP can be glued or temporarily fixed through strings, tape or any other support that would fix the GMP to the UAV. Various methods may be used to attach the structure of the GMP to the physical skid of the multi-copter.

[0021] In some embodiments, the GMP has a wheeled platform or frame (also referred to herein, collectively, as “propulsion mechanics”). Although shown and described herein to comprise wheels, any other kind of ground movement system known in the art, such as a continuous tank track, casters, etc., is also contemplated. The GMP is configured to perform or facilitate safe landing of a UAV. This can include shock absorber or damper systems, such as springs, to smooth/soften the impact with the ground. These GMP is configured to cross rough terrain and/or climb slopes.

[0022] In some embodiments, the GMP is operable completely independently from the UAV, and has an interface that is adaptable to different types and sizes of UAV. The GMP can comprise a ground/terrestrial robot capable of mobile transport, and configured to receive at least a portion of a UAV thereon or therein via the interface. The interface can have a form factor that is complementary to the at least a portion of the UAV. In some embodiments, the GMP is configured such that it does not move (i.e., remains stationary) if it is not attached to a UAV.

[0023] In some embodiments, the GMP includes a set of wheels that are configured for terrain movement. The wheels can be unidirectional, bidirectional, or multidirectional (e.g., spherical).

[0024] In some embodiments, the GMP includes a set of omni wheels that can be driven with full force, and that slide laterally with great ease.

[0025] In some embodiments, the GMP is configured to serve as an autonomous motor system for a VTOL UAV, and can be powered by a battery of the UAV and/or by an independent onboard battery.

[0026] In some embodiments, the GMP is not motorized and is instead configured to slide and shift on the ground in response to momentum imparted thereto by an external applied force such, as wind or the UAV propellers, or the engine(s) moving the UAV propellers.

[0027] In some embodiments, a GMP transportation system includes one or more features that facilitate movement (e.g., floating hull, propellers, skids, tracks, etc.) that can propel the UAV on any non-vertical surface (generally referred to herein as “ground”). Non-vertical surfaces can include the surface of a fluid, and/or a viscous, amorphous, malleable, frictionless and/or non-gaseous material such as water, sand, snow, or ice.

[0028] If motorized, the GMP can have one or multiple electronic boards, or “controllers,” for example to control the propulsion mechanics and/or communicate with a flight-control system of the UAV. In some embodiments, the GMP is fully autonomous in that it does not communicate with the flight-control system of the UAV or with any other electronic board of the UAV. In the description that follows, the terms “electronic board” and “controller” are used interchangeably, and generally include electronic circuits without being limited to printed circuit boards and the like.

[0029] In some embodiments, the GMP is configured to connect to a flight-control system board, or other electronic board, present on an attached UAV. For example, the attached UAV can have an interface (e.g., a receptacle or plug) on its flight-control board to connect to peripheral devices, and the GMP can have a complementary receptacle or plug. The connection between the GMP and the electronic board of the UAV can be used by the GMP and/or the UAV to transfer data such as commands for the movement of the GMP. The connection between the GMP and the electronic board of the UAV can be a direct connection to one or more motors of the GMP, or to the electronic board on the GMP. In some such embodiments, the GMP can be programmed and/or controlled by a software library stored in the GMP or the UAV. The software library can be customized, or commercially obtained (e.g., a software library released by the vendor of the flight-control board).

[0030] The GMP controller can include one or more integrated electronic components and/or interfaces to external devices, for example to support a long-range remote communication link. The supported communication link can be either analog or digital, and configured to transmit data via radio waves or wireless communications protocols, e.g., Wi-Fi and WLAN protocols, GSM or 3G/4G/LTE cellular transmission, IR/laser transmission systems, or other available communication medium allowing long-distance data exchange.

[0031] The communication link can be established between the controller and any other kind of transmitter/receiver that is configured to support the connection, such as a remote control, a network card of a computer, a dongle, or an antenna system of any size. In some embodiments, the communication link is used to control propulsion of the GMP as an independent device, and/or to operate the other components present in some embodiments of the GMP, such as a charger. In some embodiments, regardless of whether the GMP includes an independent communication mechanism, the GMP can be operated through a connection with an electronic board of the attached UAV.

[0032] In some embodiments, the GMP controller is configured to interface with additional components such as, but not limited to, GPS receivers, sensors, a gimbal system, a camera, a smartphone, a parachute activator, and computer processors. The GMP controller can include a high-level embedded operating system (OS), such as Linux or Android, or a full OS, such as embedded operating systems like: NuttX, FreeRTOS, SafeRTOS, VXWorx, Windriver, Robot Operating System (ROS) or a complete Linux distribution, other UNIX/POSIX OS such as MacOS, or Microsoft Windows. For embodiments in which the GMP includes a camera, the camera can be configured to collect still images and/or video, and the GMP can include a transmitter to stream videos or upload data via the communication link.

[0033] In some embodiments, the GMP includes a charger compartment, (“recharge unit”) for example disposed adjacent to or within the ground movement elements. The charger can host technology that works in conjunction to a recharging station.

[0034] Examples of chargers are: a wireless charger with receiving circuitry that is configured to receive energy from a transmitting coil through coupled inductive or capacitive electromagnetic interaction (e.g., inductive charging); an electric conduction system including a cathode and an anode that are configured/positioned to contact metallic pads of corresponding polarity; a “hot swap” battery substitution system in which the battery of the attached UAV is electro-mechanically substituted with a battery provided by the GMP or docking station, for example within the charger compartment; a fuel-cell system that supplies power via loading of chemical fuel in encapsulated or solid, liquid, gaseous form.

[0035] The charger compartment, or recharge unit, can also be used to physically host the application board of the GMP, as well as any other additional electronics present in advanced embodiments of the GMP, such as sensors or companion computers.

[0036] The GMP controller can be electronically integrated with the charger and/or additional electronic components. In other words, the charger can be used to supply power to any other electronics in the GMP and/or the UAV. For example, in some embodiments, package release mechanics onboard the GMP are only powered when the UAV is docked.

[0037] In some embodiments, the GMP includes onboard electronics, and the GMP is configured to interface/connect with a power source, for example to power the propulsion of the GMP. In some embodiments, the power source is the same power source powering the UAV, for example a battery onboard the UAV. The connection to the power source can be direct or via the charger.

[0038] In some embodiments, the GMP can host a module that allows the GMP to interact remotely with a nearby recharging station. This interaction is meant to assist the docking procedure via the movements allowed by the GMP. The module could be, for instance, a dedicated electromagnetic waves transmission module, a visual recognition system, a localization and alignment method using lasers, other forms of light, sound waves such as ultrasounds, or it could use physical hardware extensions such as light tethers or elongated artificial whiskers.

[0039] In some embodiments, the operation of the GMP through the external link can be assisted by a human pilot which controls the movement of the GMP and of the attached UAV manually. For example, the GMP could be directed into positioning in the appropriate area of a docking station in First Person View pilot mode, by means of real-time video streaming from the cameras installed on the UAV or on the GMP.

BRIEF DESCRIPTION OF THE DRAWINGS

[0040] In order to illustrate the way in which the above mentioned advantages and features of the embodiments can be obtained, a brief description of the components is provided in the appended drawings. It needs to be underlined that the figures are not drawn to scale, and similar elements, in terms of function or shape, are indicated through reference numerals; the drawings should be considered as illustrations of typical embodiments without limiting of the scope.

[0041] FIG. 1 is a block diagram representing the interaction of components in GMP systems, according to some embodiments.

[0042] FIG. 2 is a rendering of a GMP vehicle attached to a UAV, according to an embodiment.

[0043] FIG. 3 is a rendering of a UAV hovering above a GMP vehicle, according to an embodiment.

[0044] FIG. 4 is an exploded rendering of a UAV and GMP vehicle, according to an embodiment.

[0045] FIG. 5 is a rendering of a perspective view of a GMP vehicle, according to some embodiments.

[0046] FIG. 6A is a rendering of a top view of the GMP vehicle of FIG. 5.

[0047] FIG. 6B is a partially exploded rendering of a top view of the GMP vehicle of FIG. 5.

[0048] FIG. 7 is a rendering of a detail view of the GMP vehicle of FIG. 5.

[0049] FIG. 8 is a rendering of a UAV hovering above the GMP vehicle of FIG. 5, according to an embodiment.

[0050] FIG. 9 is a rendering of a UAV with an integrated GMP vehicle, along with an example landing location and lateral location to which the UAV will move after landing.

DETAILED DESCRIPTION

[0051] Current technological developments in the field of vertical take-off and landing (VTOL) unmanned aerial vehicles (UAVs) include ground stations that supply power to the UAVs and/or that serve as docking areas. However, UAVs do not always effectively reach these stations when landing operations are completed - a task made particularly difficult in adverse weather conditions, when the process can be disturbed by external factors, such as rain or wind, or impaired by low visibility.

[0052] Automatic landing is a difficult task which must be carried out with great care in order to avoid damage to the UAV. Various types of automatic landing systems have been proposed. However, none of the previously proposed systems of this type provides an adequate and sufficiently reliable method by which a safe, autonomous landing can be achieved during adverse weather conditions. Moreover, there is a need for a system that, in addition to the capability of landing a VTOL UAV safely, can direct the UAV to a target location, once it has landed, by using an automatic repositioning system. Previously, multi-copters with fixed wheels have been proposed and are currently in use. The current commercialized systems have wheels that are directly integrated in the vehicle airframe, and not motorized. For example, current systems exploit the UAV propellers' air displacement in order to provide movement on the ground, and are mostly directed at products for recreational use. Ground propulsion for non-flying robots comes in many forms, and a variety of transport methods have been proposed for ground mobility of electromechanical systems, such as rows of wheels, continuous tank tracks, and artificial articulating legs. Other technologies include UAV plug-ins that differ from those described herein. Examples are gimbals for cameras or any other removable support for data acquisition sensors or other hardware extensions enabling, for example, indoor navigation through on-board systems that interface with additional hardware positioned on the ground.

[0053] Still other technologies include flight control and movement control electronic boards that allow the programmability of flights through application program interfaces (API), released by a vendor within a software development kit (SDK). Such APIs can be wrapping standard

proprietary or open source communication protocols, and used to define the flight instructions (such as Mavlink), or could be based on an entirely new programming language for controlling a specific UAV/robot.

[0054] Other related technology includes landing platforms for VTOL UAVs, for example recharging/docking stations, whose working principle is based on the exact positioning of the UAV and its vertical landing on the required spot (i.e., precision landing).

[0055] Other related technology also includes ground robot docking stations, accessible to the robots through mechanical or electromagnetic guides, that align the UAV with the robot and allow it to interface with the docking system. These known systems and methods to assist the docking of ground robots have never been applied to UAVs, as they are not traditionally capable of moving on the ground.

[0056] The present disclosure is directed to terrestrial ground movement plug-in (GMP) vehicles that are designed to attach to a UAV, either prior to/during flight or after landing, and to provide functionality for terrestrial transport of the UAV (e.g., so that the UAV effectively becomes a ground robot). GMP vehicles described herein facilitate landing and/or movement of UAVs, and have sufficient space to accommodate sensors and/or other hardware, such as a recharger interface. GMP vehicle systems described herein allow UAVs to fully exploit the plethora of methods of movement and interaction with docking stations that are already available for ground robots, as well as enabling the execution of new movements and interactions.

[0057] Embodiments of the present disclosure are described hereinafter with reference to the accompanying drawings, in which one or more, but not all the embodiments of the invention are shown in each figure. Indeed, the present invention can be embodied in many different forms and should not be considered as being limited to the embodiments set forth herein. In the drawings, thick arrows indicate a connection between components, and dashed arrows indicate an optional connection between components.

[0058] In some of the descriptions set forth below, a VR Spark quadcopter or variations of a VR Mapper quadcopter is used as an example, however other types of UAV can be used.

[0059] FIG. 1 is a block diagram representing the interaction of components in some embodiments of GMP systems 100. Each arrow represents a possible connection (e.g., a physical connection and/or a connection that is configured for data transmission). Dashed squares represent optional components of the envisioned system. As shown in FIG. 1, the GMP system 100 includes GMP propulsion mechanics 102 operably coupled to a GMP controller 104, and a power supply 106 (e.g., one or more batteries). The power supply 106 can be disposed within the GMP, within the UAV, or both. The power supply 106 can be operably coupled to an optional charger 108,

which may be disposed on board the GMP vehicle itself, or external to the GMP vehicle, with the GMP vehicle being configured to make an electrical connection therewith. The GMP controller 104 is optionally coupled to a UAV electronic board 110 (e.g., a flight control system) of a UAV when the UAV is at least partially disposed on or in the GMP), for example to receive data and/or power from the UAV. The UAV electronic board 110 and/or the GMP controller 104 can be operably coupled to one or more sensors 114 onboard the GMP, the UAV, or both. The UAV (e.g., via the UAV electronic board 110), sensors 114, and/or the GMP controller 104 can be in communication with one or more remote terminals via an optional remote link, for example to send or receive data.

[0060] FIG. 2 is a rendering of a UAV 230 attached to a GMP vehicle 220, according to an embodiment. In this embodiment, the position of the center of gravity of the UAV, when attached, mounted, or assembled to the GMP vehicle, ensures stability during maneuvers on the ground and/or during adverse weather conditions.

[0061] FIG. 3 is a rendering of a UAV 330 hovering above a GMP vehicle 320, according to an embodiment of the invention. A plugin skeleton or “frame” 323 is the central component of the GMP vehicle, and it connects a ground propulsion motor 322 and the wheels 324 together, in addition to acting as the interface/adaptor onto which the UAV 330 can land/attach. In the embodiment of FIG. 3, the GMP 320 is also connected to a companion computer 325 having functions such as: image and video capture, a central processing unit (CPU) for image processing, modules for communications via radio / WiFi / 4G, and wireless recharging.

[0062] FIG. 4 is an exploded rendering of a UAV and GMP vehicle, showing internal components thereof, according to an embodiment of the invention. The UAV includes four propeller blades 441 driven by a motor for propeller blades 443 and connected to a first portion 444 of a UAV shell, which includes a removable battery compartment cover 442. The UAV includes an inner frame 445 having an integrated electronic speed controller, a radio telemetry module 447, a GPS unit 448, a flight-control system board 449, and a central printed circuit board 446 connecting different electronic components together (e.g., 447, 448 and 449). Another portion, 450, of the UAV shell is connectable directly to the plugin skeleton 423 of the GMP vehicle. The plugin skeleton 423 connects the ground propulsion motors 422A and 422B with corresponding pairs of wheels 424A and 424B (respectively), a companion computer 455 (e.g., a smartphone) and a GMP-dedicated control board 454. The UAV shell can be defined by components 442, 444, 445 and 450 (the battery compartment cover, first shell portion, inner frame, and second shell portion, respectively).

[0063] FIG. 5 is a rendering of a perspective view of a GMP vehicle, according to some embodiments. The GMP vehicle 520 includes three multidirectional wheels 524 each attached to

the frame of the GMP vehicle 520 via a corresponding servo 522. The GMP vehicle 520 also includes a companion computer 554 (e.g., a mobile device such as a cell phone) mounted to its underside. The space under the frame of the GMP can also be used as compartment for a charging unit 555 (e.g., a contact or contactless charging system/unit). FIG. 6A is a rendering of a top view of the GMP vehicle 520 of FIG. 5.

[0064] FIG. 6B is a partially exploded rendering of a top view of the GMP vehicle of FIG. 5. When assembled, wheels 562 and 563 are secured to a pivot 564 by a clamping block 561. The pivot 564 is mounted to a servo 565, which is attached to a mounting block 566.

[0065] FIG. 7 is a rendering of a detail view of the GMP vehicle of FIG. 5.

[0066] FIG. 8 is a rendering of a UAV hovering above the GMP vehicle of FIG. 5, according to an embodiment. The UAV 530 is a specific version of the VR Mapper / Wasp that is being positioned on top of the GMP embodiment 520 described above with reference to FIGS 5-7. The relative proportions of the GMP to the UAV can vary between embodiments.

[0067] FIG. 9 is a rendering of a UAV with an integrated GMP vehicle, along with an example landing location and a predetermined location to which the UAV will move after landing. In this example of landing procedure, the UAV 930, with attached GMP 920, can land in any of the region marked "L," with variation depending, for example, on imprecise position data (e.g., GPS data) and/or adverse weather conditions, or any other lack of control. Once the UAV 930/GMP 920 has landed within the region "L," the UAV 930/GMP 920 can move along the ground to the predefined spot "S" through propulsion by the GMP.

[0068] Although the disclosed subject matter has been described and illustrated in the foregoing exemplary embodiments, it is understood that the present disclosure has been made only by way of example, and that numerous changes in the details of implementation of the disclosed subject matter may be made without departing from the spirit and scope of the disclosed subject matter.

What is claimed is:

1. An apparatus for providing ground propulsion to an unmanned aircraft vehicle (UAV), the apparatus comprising:
 - a frame configured to mechanically couple with the UAV;
 - a plurality of wheels, at least one wheel of the plurality of wheels actuatable by a motor; and
 - a controller operably coupled to the motor to control propulsion of the apparatus.
2. The apparatus of claim 1, wherein the controller is adapted to interface, in use, with at least one of an electronic board of the UAV and a remote control unit.
3. The apparatus of claim 1, wherein the frame is configured to mechanically and electrically couple to a computer.
4. The apparatus of claim 1, further comprising a charger configured to connect to and recharge a battery of the UAV during use.
5. The apparatus of claim 4, wherein the charger is a wireless charger.
6. The apparatus of claim 1, wherein, when the frame is coupled with the UAV, the apparatus is electrically coupled to the UAV.
7. The apparatus of claim 6, wherein, when the frame is coupled with the UAV, the apparatus receives electrical power from a power supply of the UAV.
8. The apparatus of claim 1, wherein the frame includes an adapter configured to at least one of mechanically and electrically couple to the UAV.
9. The apparatus of claim 8, wherein the adapter is configured to at least one of mechanically and electrically couple to any one of a plurality of UAV types.
10. The apparatus of claim 1, further comprising a battery.

11. The apparatus of claim 1, further comprising at least one of a GPS receiver and an antenna.
12. The apparatus of claim 1, further comprising a gimbal.
13. The apparatus of claim 1, further comprising a computer operably coupled to the controller, the computer including a processor and a non-transitory memory storing processor-issuable instructions to drive the motor.
14. The apparatus of claim 13, further comprising a sensor to receive position data, the non-transitory memory storing processor-issuable instructions to drive the motor to reposition the vehicle based on the position data.
15. The apparatus of claim 14, wherein the sensor includes one of: a GPS receiver, an accelerometer, a gyroscope, LIDAR, or a visual recognition system.
16. The apparatus of claim 14, wherein the position data includes at least one of: position data of the vehicle; and position data of a UAV.
17. The apparatus of claim 14, wherein the computer further includes a camera configured to capture at least one of video and still images.
18. The apparatus of claim 17, further comprising an image processor to process the at least one of video and still images.
19. The apparatus of claim 13, wherein the computer further includes an antenna configured to communicate with a remote terminal.
20. The apparatus of claim 19, wherein the remote terminal is a UAV.
21. The apparatus of claim 19, wherein the remote terminal is a docking station.

22. A system, comprising:
a UAV; and
the apparatus of claim 1.
23. A method for providing ground propulsion to an unmanned aircraft vehicle (UAV), the method comprising:
coupling the UAV to a propulsion apparatus, the propulsion apparatus including:
a frame configured to mechanically couple with the UAV;
a plurality of wheels, at least one wheel of the plurality of wheels being actuatable by a motor; and
a controller operably coupled to the motor to control propulsion of the apparatus, and
controlling the propulsion apparatus using the controller to propel the UAV.
24. An apparatus for providing ground propulsion to an unmanned aircraft vehicle (UAV), the apparatus comprising:
a propulsion device including at least one of a continuous track and a mechanical leg; and
a frame configured to mechanically couple with the UAV.
25. The apparatus of claim 24, wherein the propulsion device is configured to actuate, during use, in response to an externally applied force.
26. The apparatus of claim 25, wherein the externally applied force is wind.
27. The apparatus of claim 26, wherein the externally applied force is applied by motor of the UAV.
28. The apparatus of claim 24, further comprising the UAV.

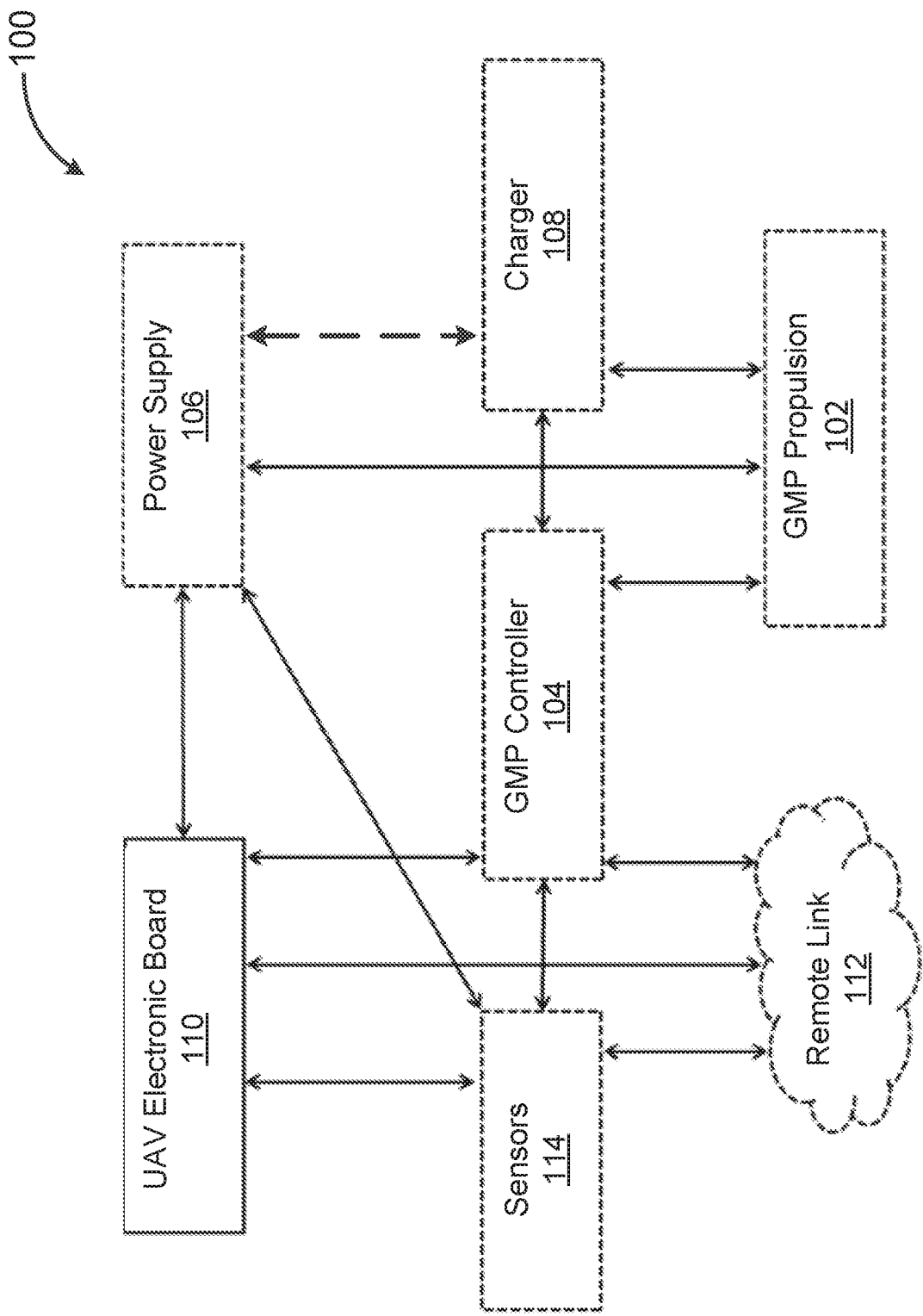


FIG. 1

2/10

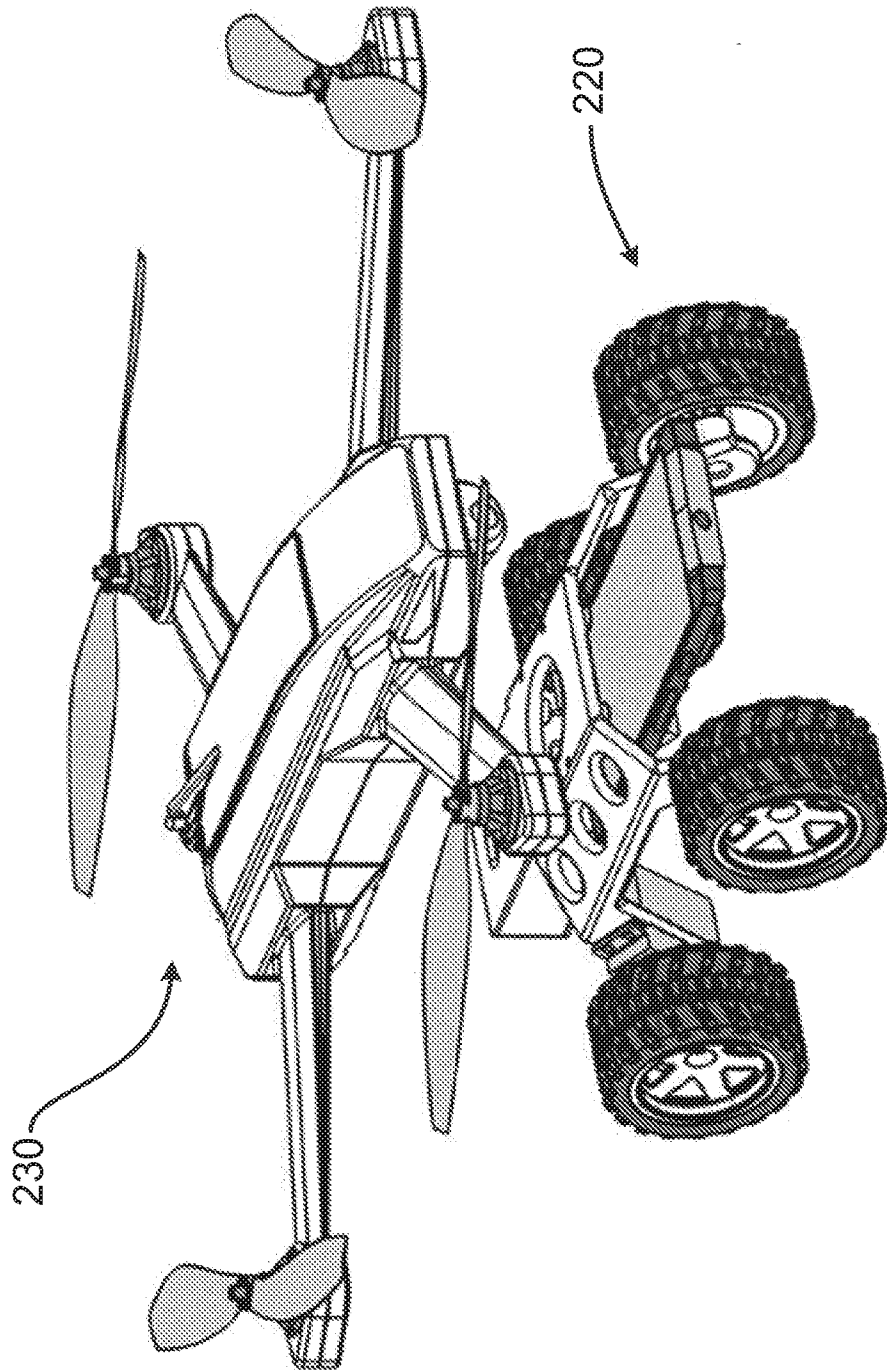


FIG. 2

3/10

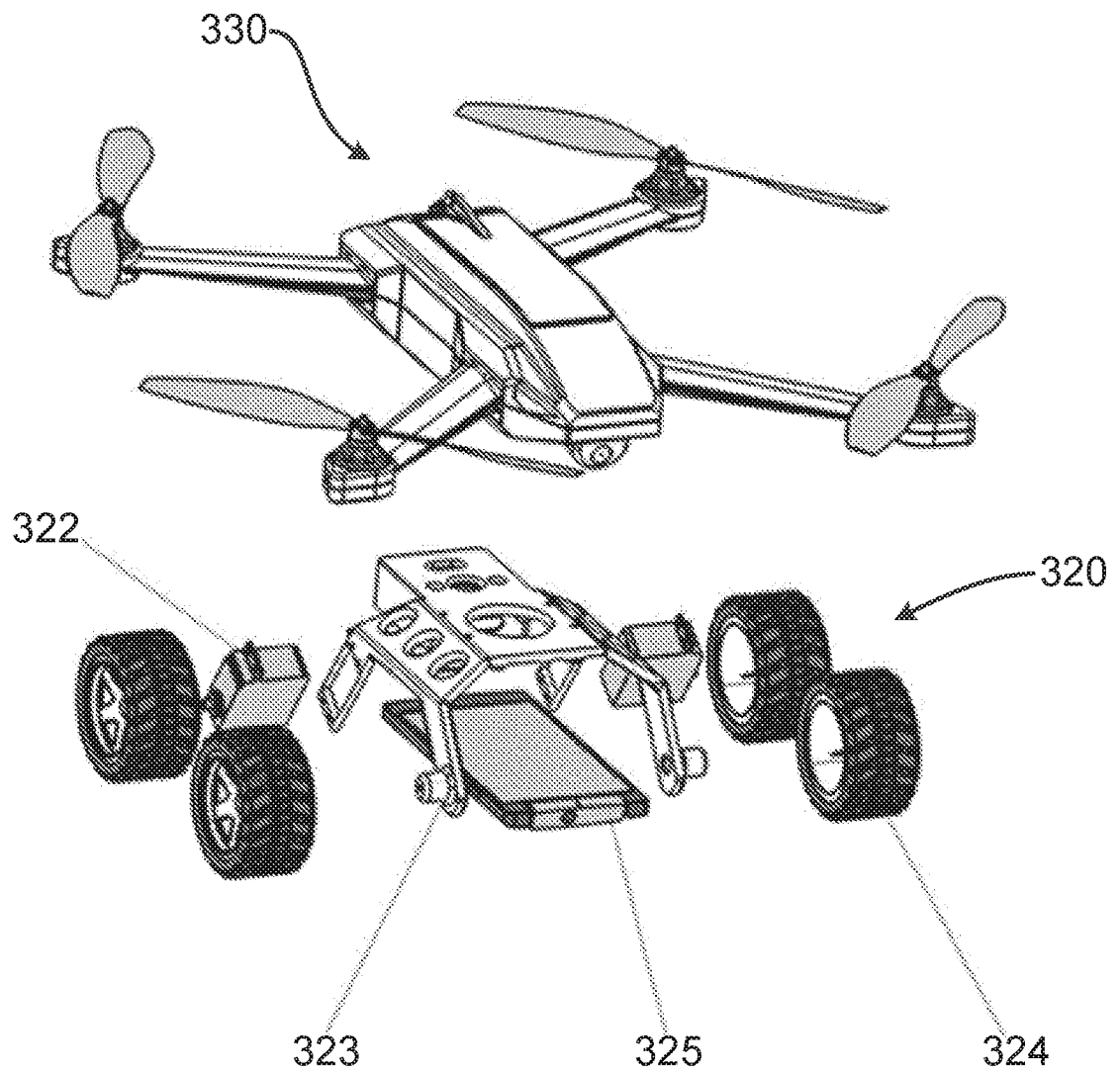


FIG. 3

4/10

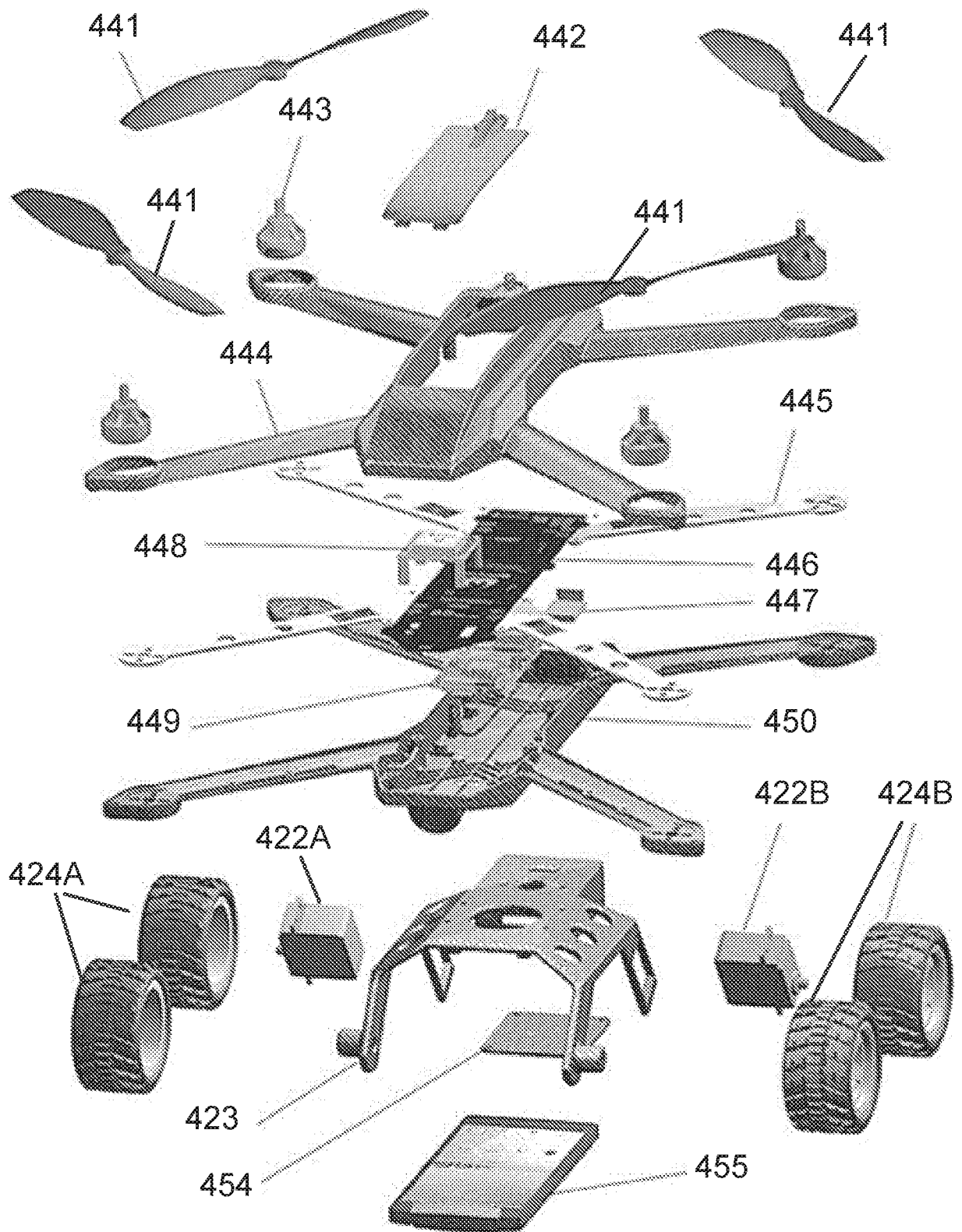


FIG. 4

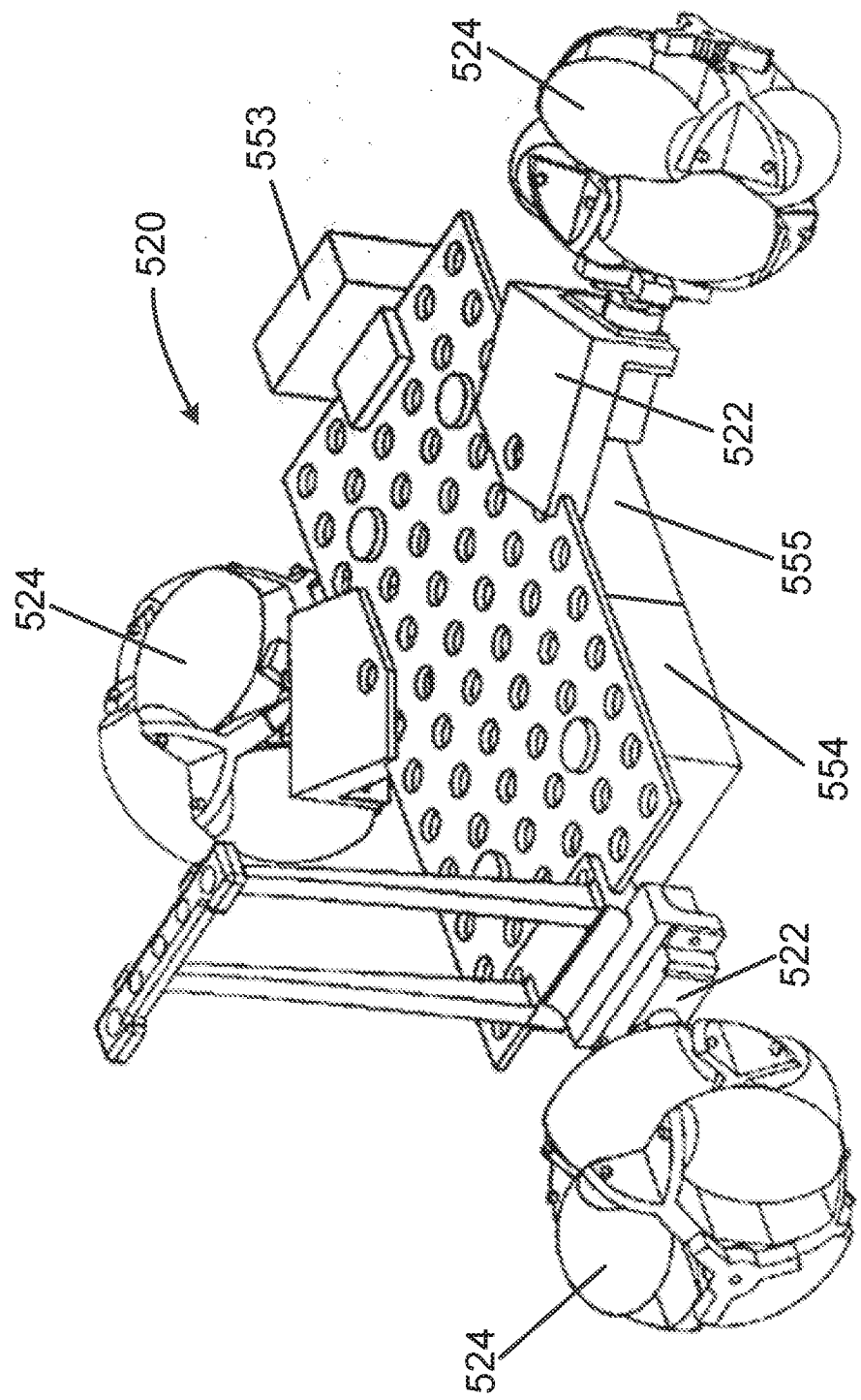


FIG. 5

6/10

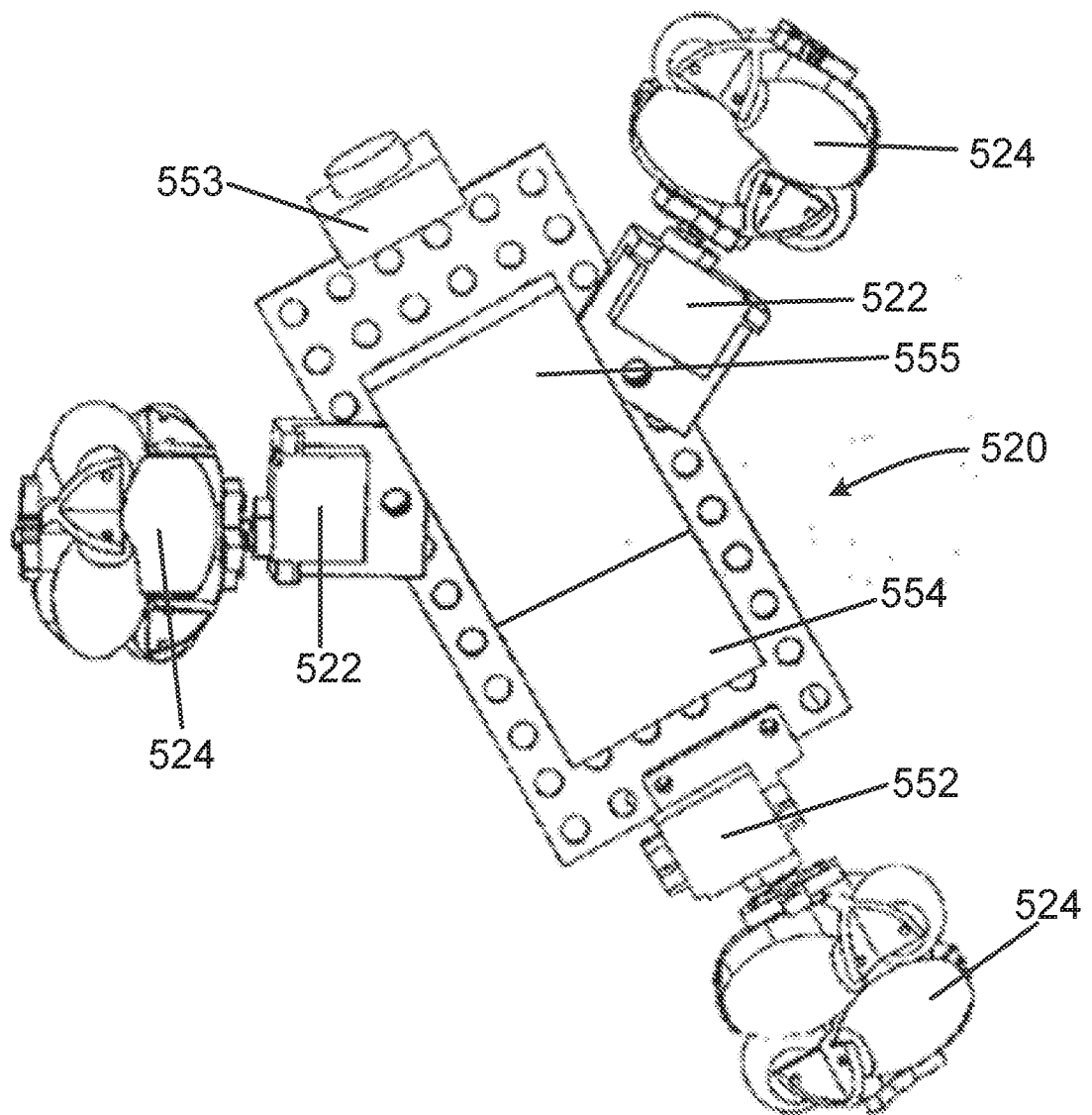


FIG. 6A

7/10

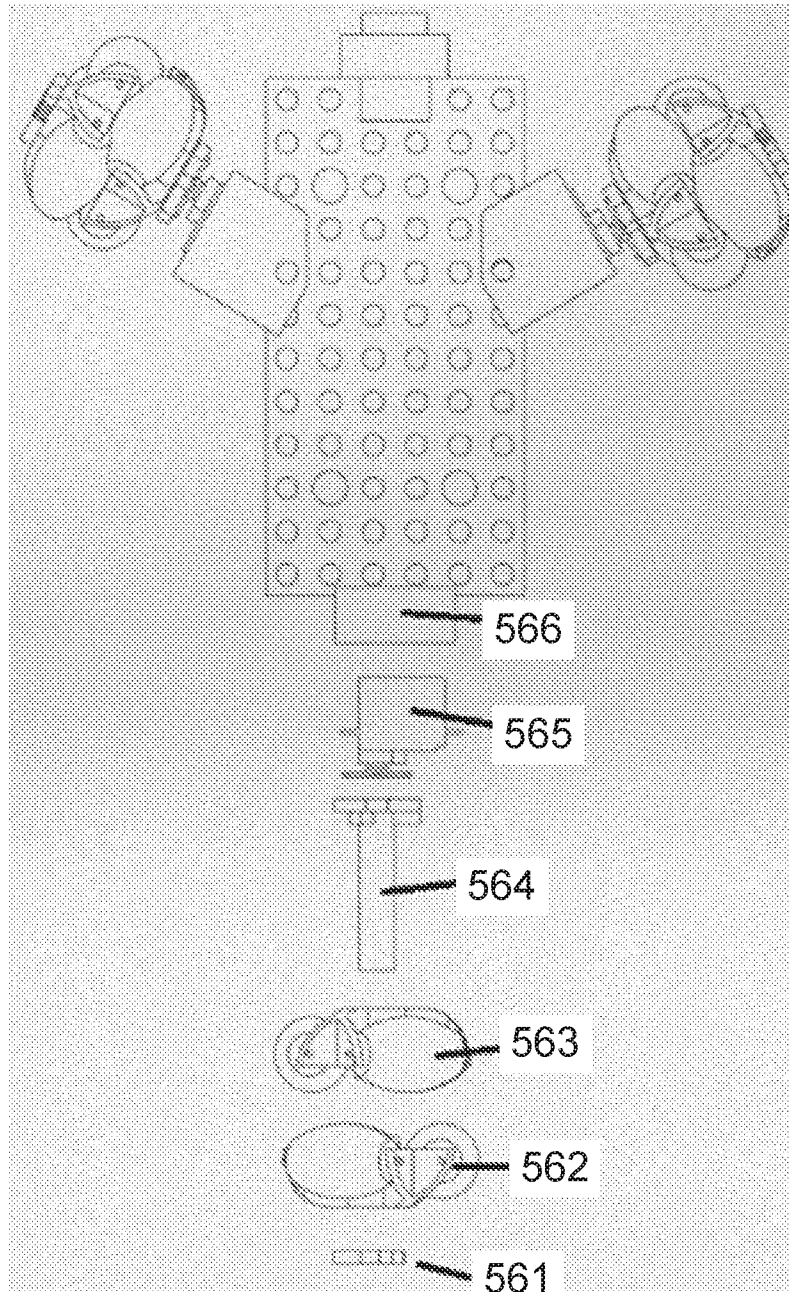


FIG. 6B

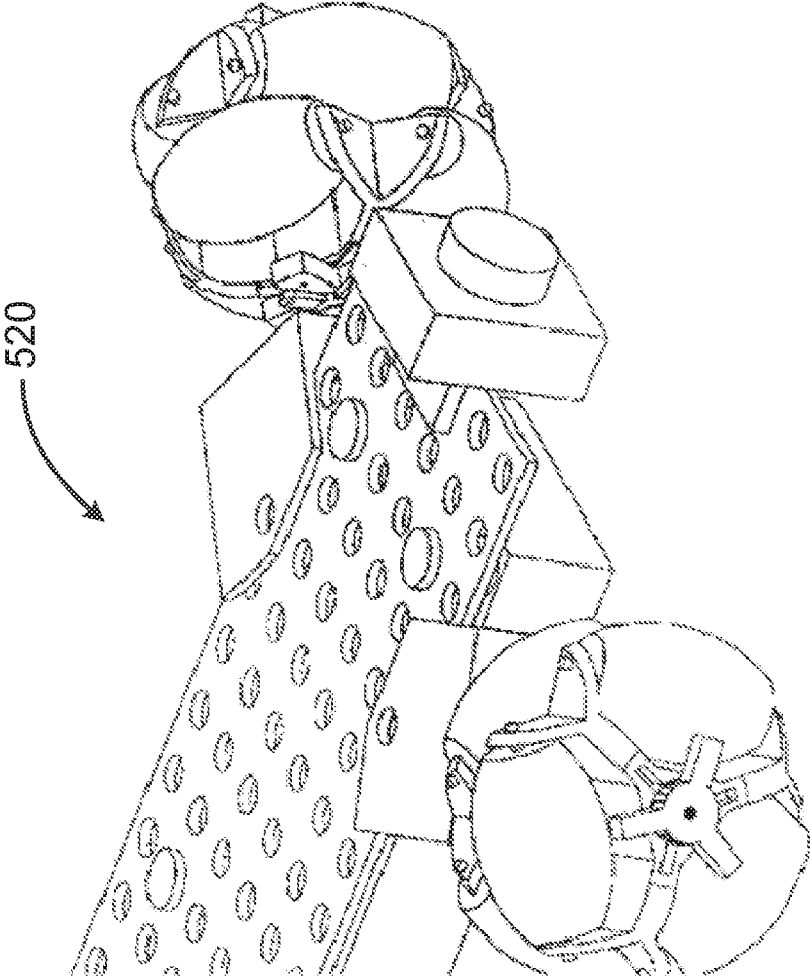


FIG. 7

9/10

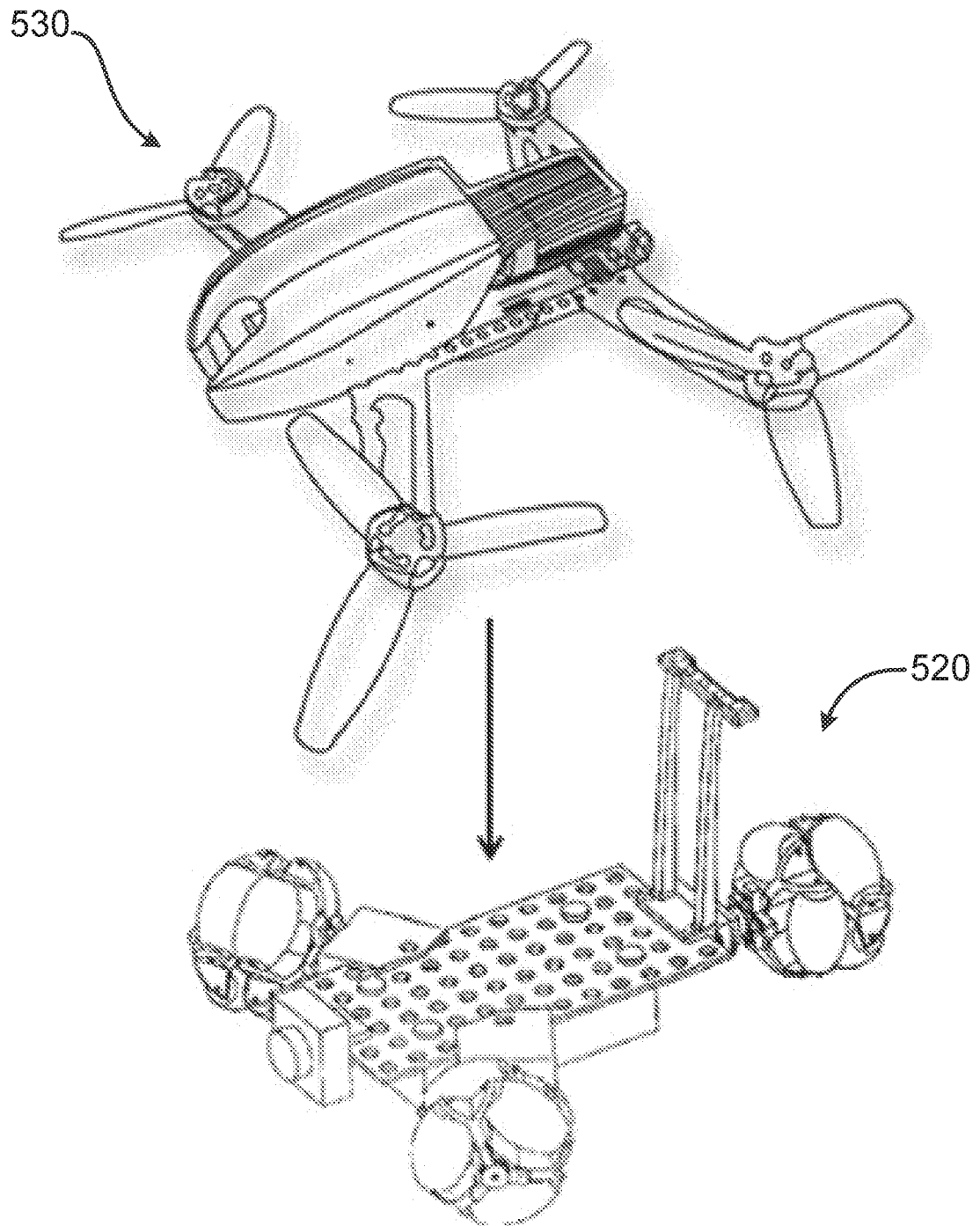


FIG. 8

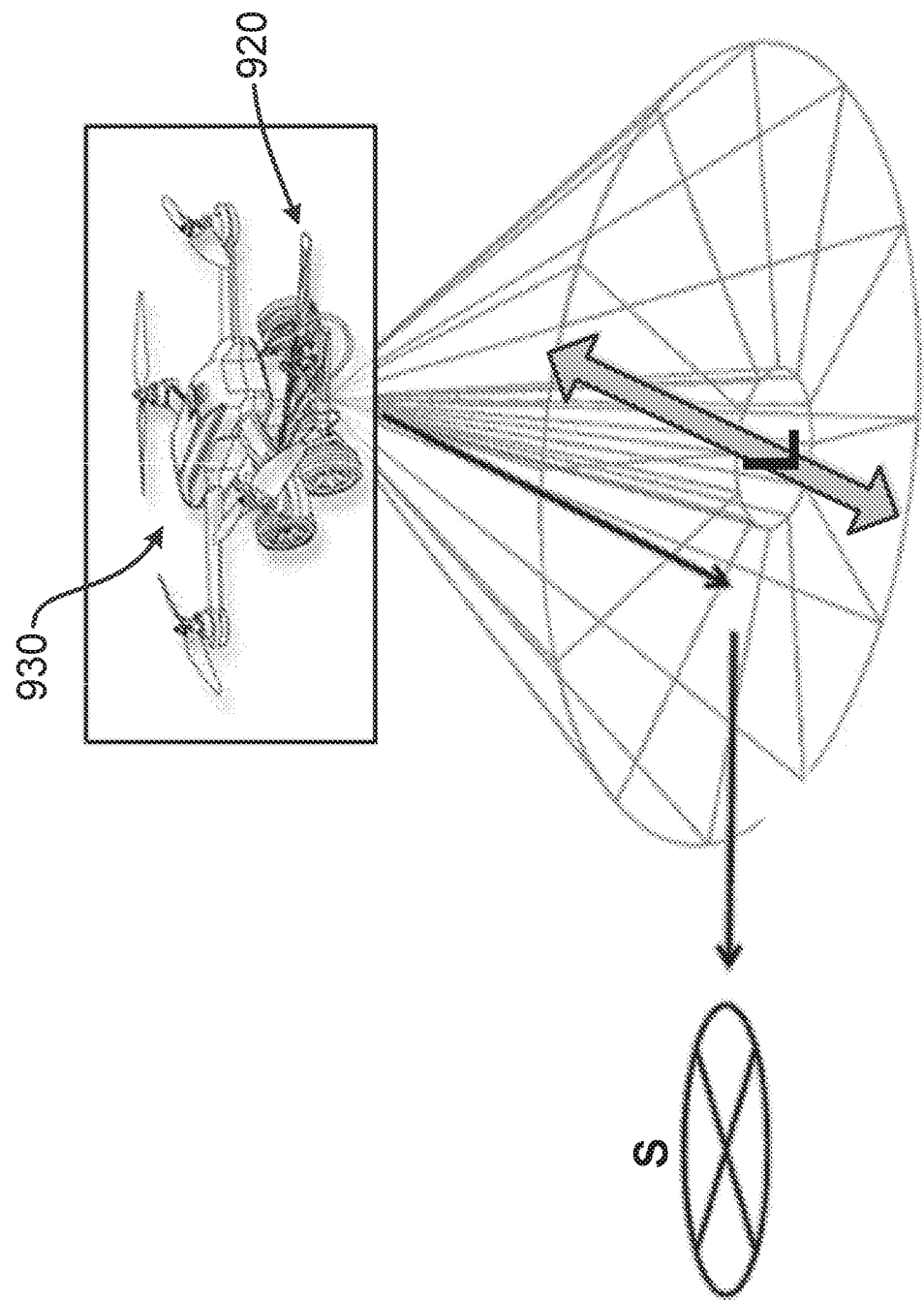


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US16/26152

A. CLASSIFICATION OF SUBJECT MATTER IPC(8) - B64C 25/32, 25/34, 25/40 (2016.01) CPC - B64C 25/40, 25/405 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC(8) Classifications: B64C 25/32, 25/34, 25/36, 25/38, 25/40, 25/44, 27/08; B64F 1/04 (2016.01) CPC Classifications: B64C 25/32, 25/40, 25/405, 2201/027, 2201/042, 2201/146; Y02T 50/823 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched USPC Classifications: 244/50 Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) PatSeer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, INPADOC Data); UAV, unmanned aerial vehicle, drone, unmanned aerial platform, wheels, motor, ground propulsion, ground travel, taxi, gimbal, receiver, antenna, gps, dock, station, battery, charge, recharge, ugv, unmanned ground vehicle, recovery, launch		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X — Y	US 2010/0193626 A1 (GOOSSEN E. R. et al.) August 5, 2010; figure 6; paragraphs [0016], [0030], [0044]	1-3, 6-9, 22-28 — 4, 5, 11, 12
X	US 2013/0214089 A1 (BOREALIS TECHNICAL LIMITED) August 22, 2013; figure 1; paragraphs [0030], [0031], [0037]	1, 10
Y	US 2009/0314883 A1 (ARLTON P. E. et al.) December 24, 2009; figure 1; paragraphs [0023], [0042], [0047]	4, 5, 15, 17, 18
Y	US 2012/0160024 A1 (PHILLIPS F. et al.) June 28, 2012; paragraph [0006]	11
Y	'GROUNDRIIG UGV LONG RANGE GIMBAL BUGGY' (PROVIDENTIAL SYSTEMS) Retrieved from the internet on May 31, 2016. April 4, 2015. URL: < https://web.archive.org/web/20150404001720/http://www.providentialsystems.com/2015/02/17/groundriig-ugv-long-range-gimbal-buggy/ >	12
Y	'New control method enables drones to lang autonomously on moving vehicles' (LAVARS N.) Retrieved from the internet on May 31, 2016. August 20, 2014. URL: < http://www.gizmag.com/control-method-drones-autonomous-docking-moving-vehicles/33448/ >	1, 13-21
Y	US 2015/0076285 A1 (CHAVEZ C. C. JR.) March 19, 2015; paragraph [0021]	1, 13-21
A	WO 2011/149544 A1 (FISHER C. E. et al.) December 1, 2011; entire document	1-28
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 31 May 2016 (31.05.2016)		Date of mailing of the international search report 08 JUL 2016
Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300		Authorized officer Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774