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(54) **CALIBRATION TRANSFER BETWEEN TWO DEVICES**

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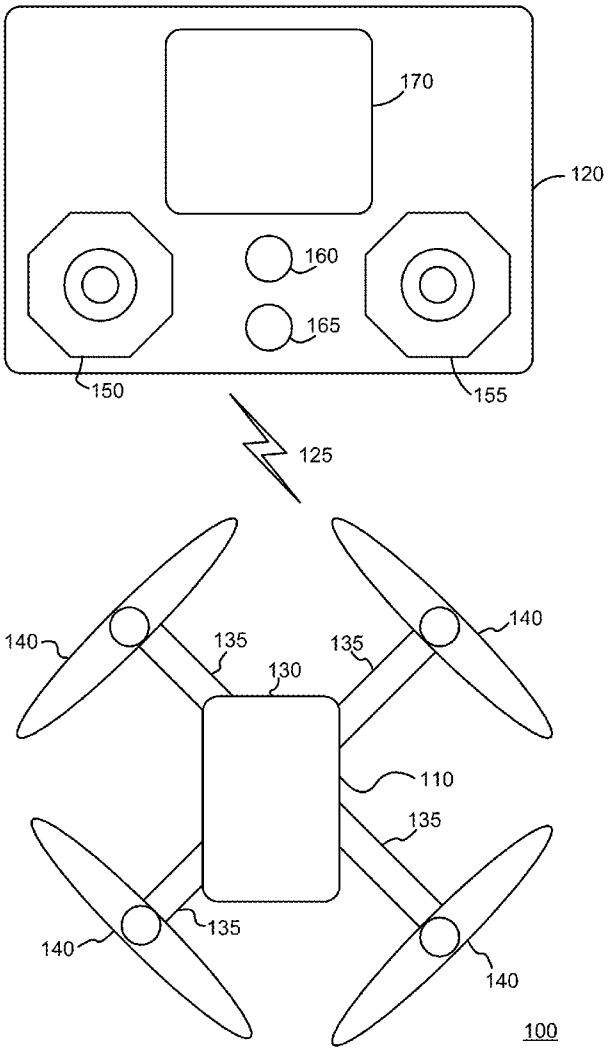
CPC ***G01C 17/38*** (2013.01); ***H04L 67/12*** (2013.01)

(57) **ABSTRACT**

Disclosed is a system to automatically calibrate a compass (e.g., a compass with a magnetometer) of an aerial vehicle. Auto calibration may occur at power up of the aerial vehicle or shortly thereafter. The system may be configured to rotate a gimbal, coupled with the aerial vehicle, in a wide range of rotational angles. The system may calibrate, in response to the rotations, a compass of the gimbal to obtain one or more calibration values and transfers the one or more calibration values to the aerial vehicle. The system may add a calibration difference value to the calibration value to obtain an adjusted calibration and may store the adjusted calibration for use with the compass of the aerial vehicle.



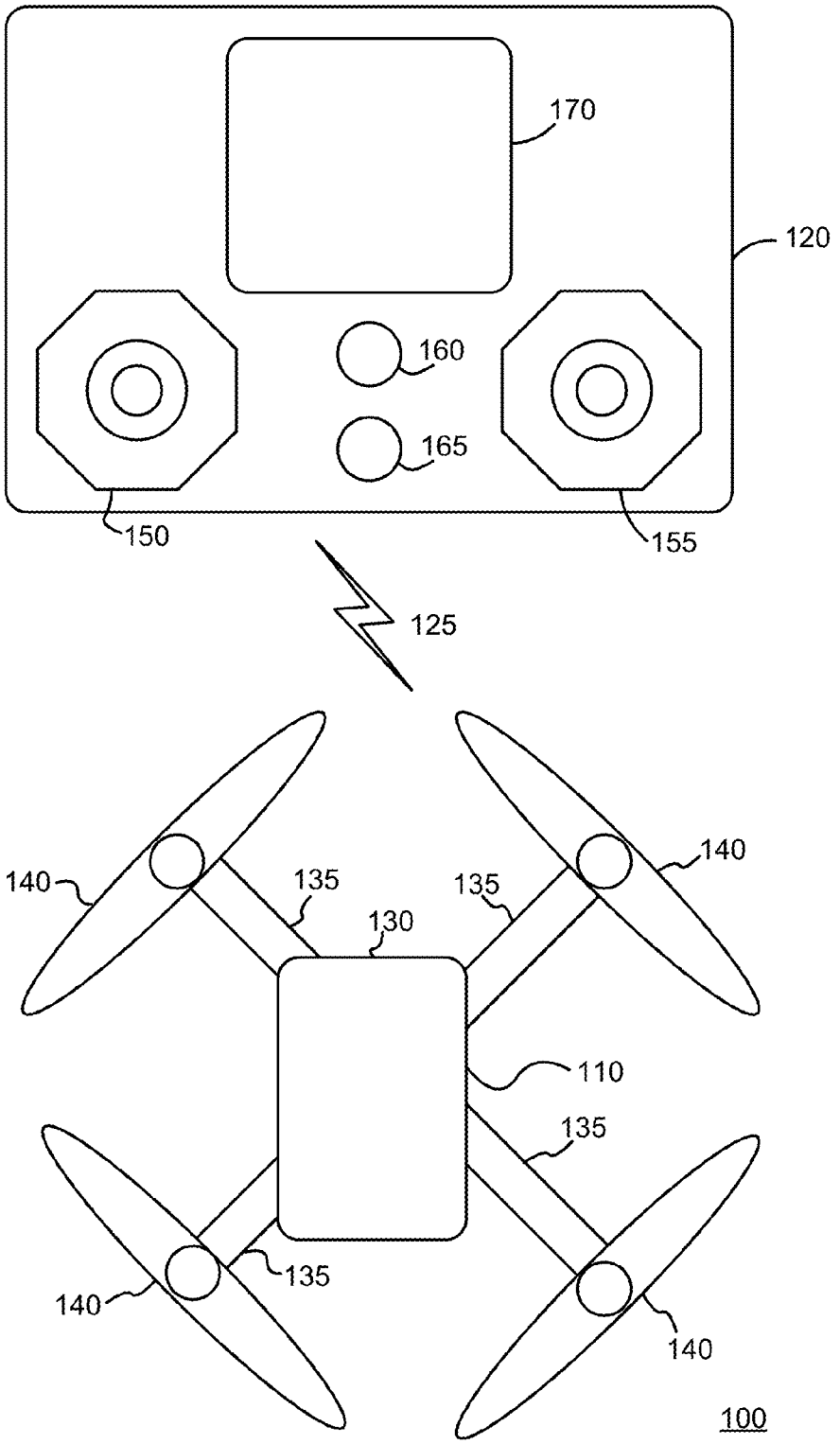

170
120
160
165
150
155
125
140
135
135
140
130
110
135
135
140
140
100

FIG. 1

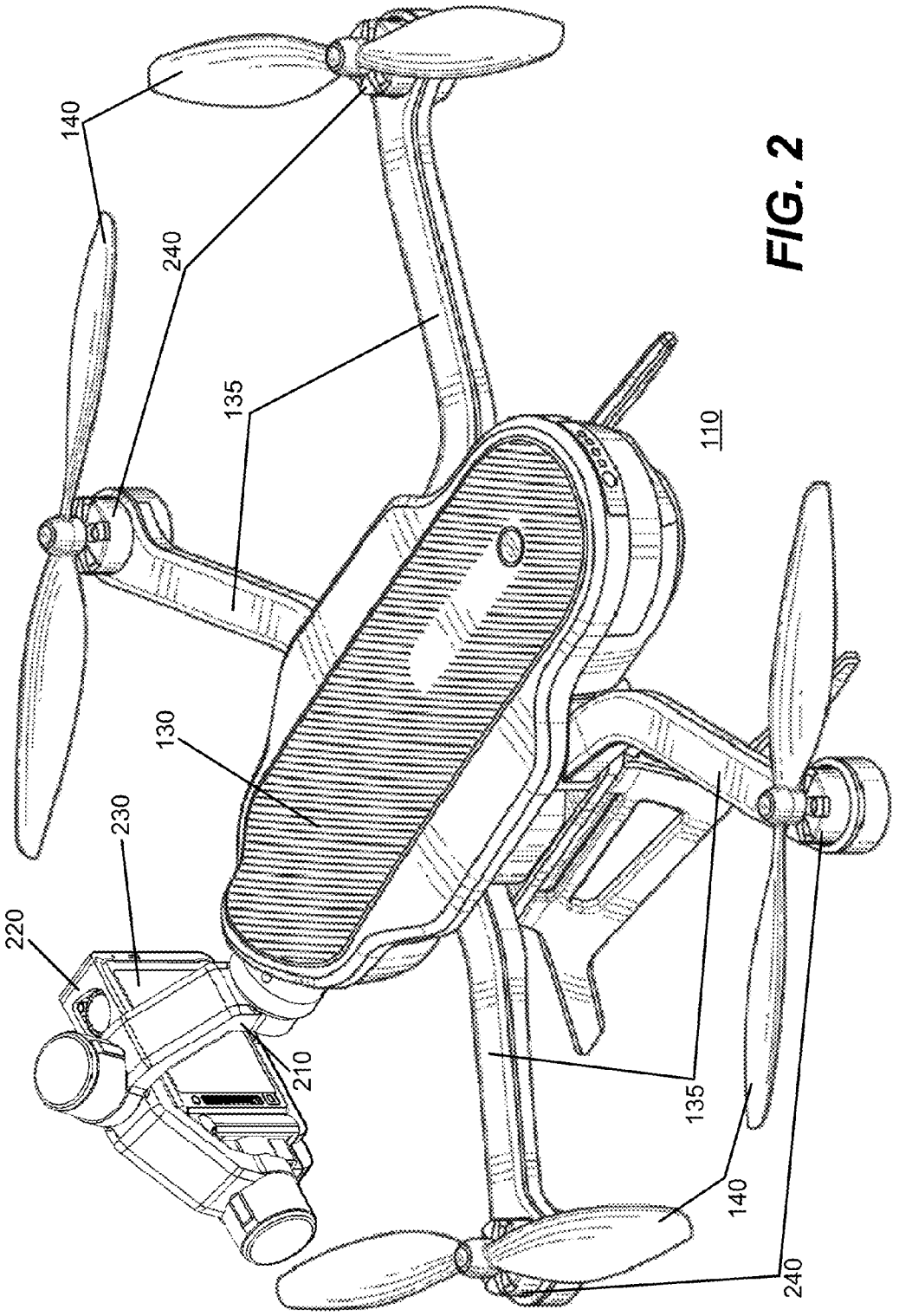
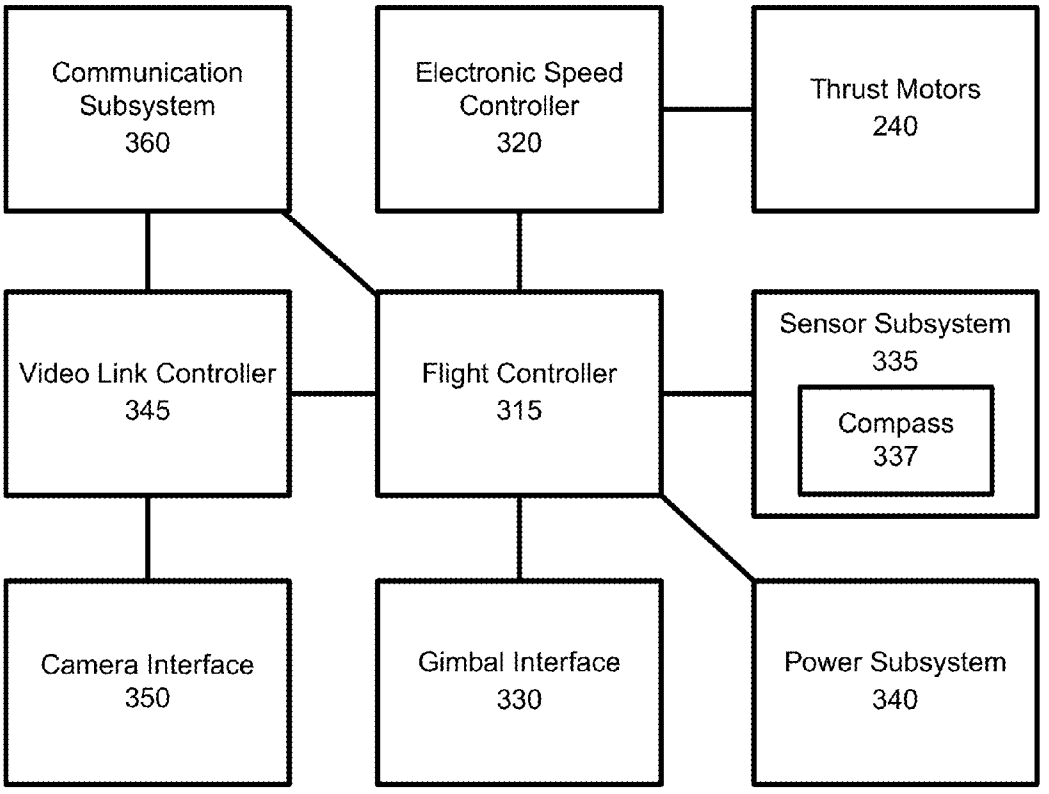


FIG. 2

FIG. 3


Communication Subsystem 360
Electronic Speed Controller 320
Thrust Motors 240
Video Link Controller 345
Flight Controller 315
Sensor Subsystem 335
Compass 337
Camera Interface 350
Gimbal Interface 330
Power Subsystem 340
310

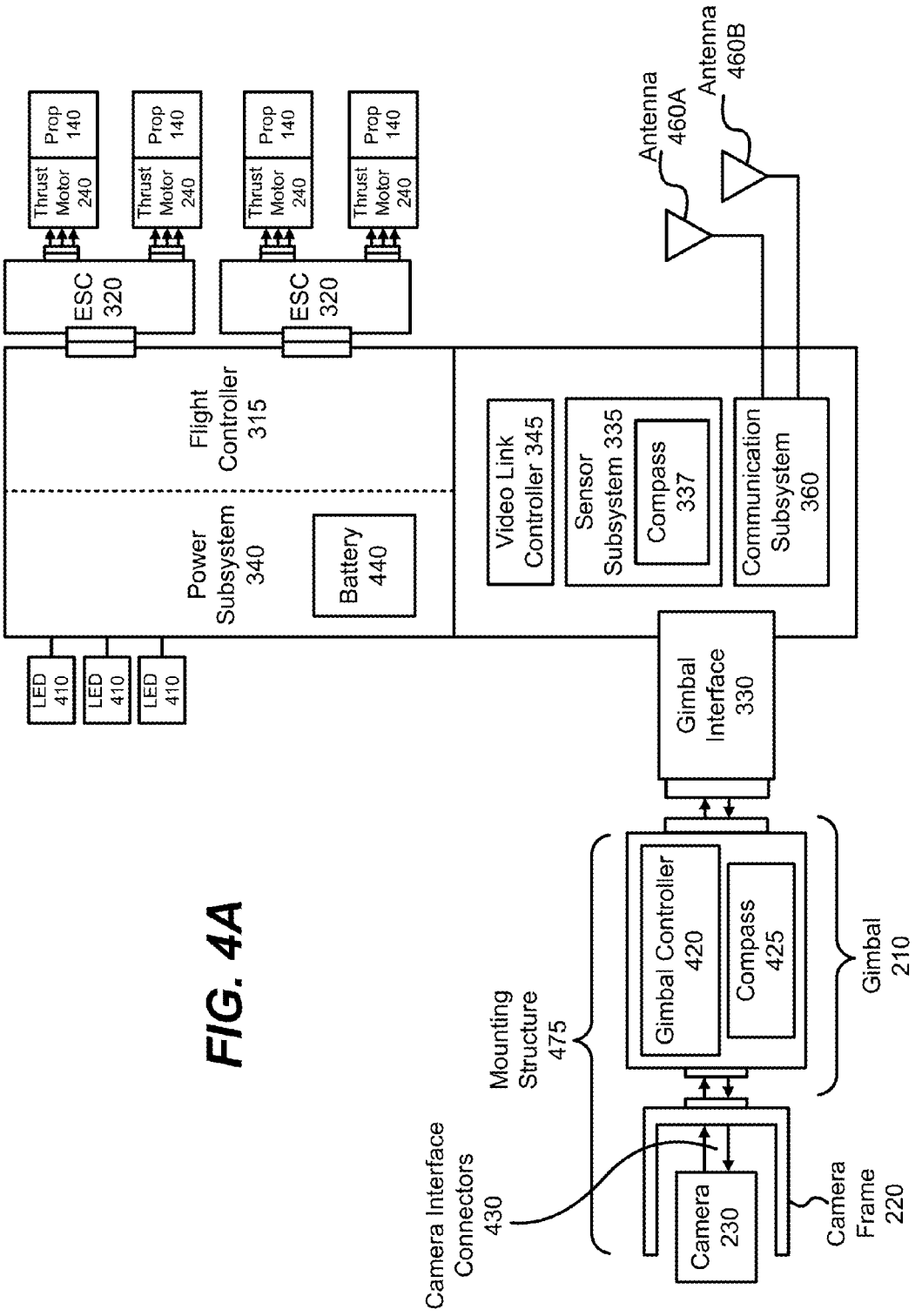
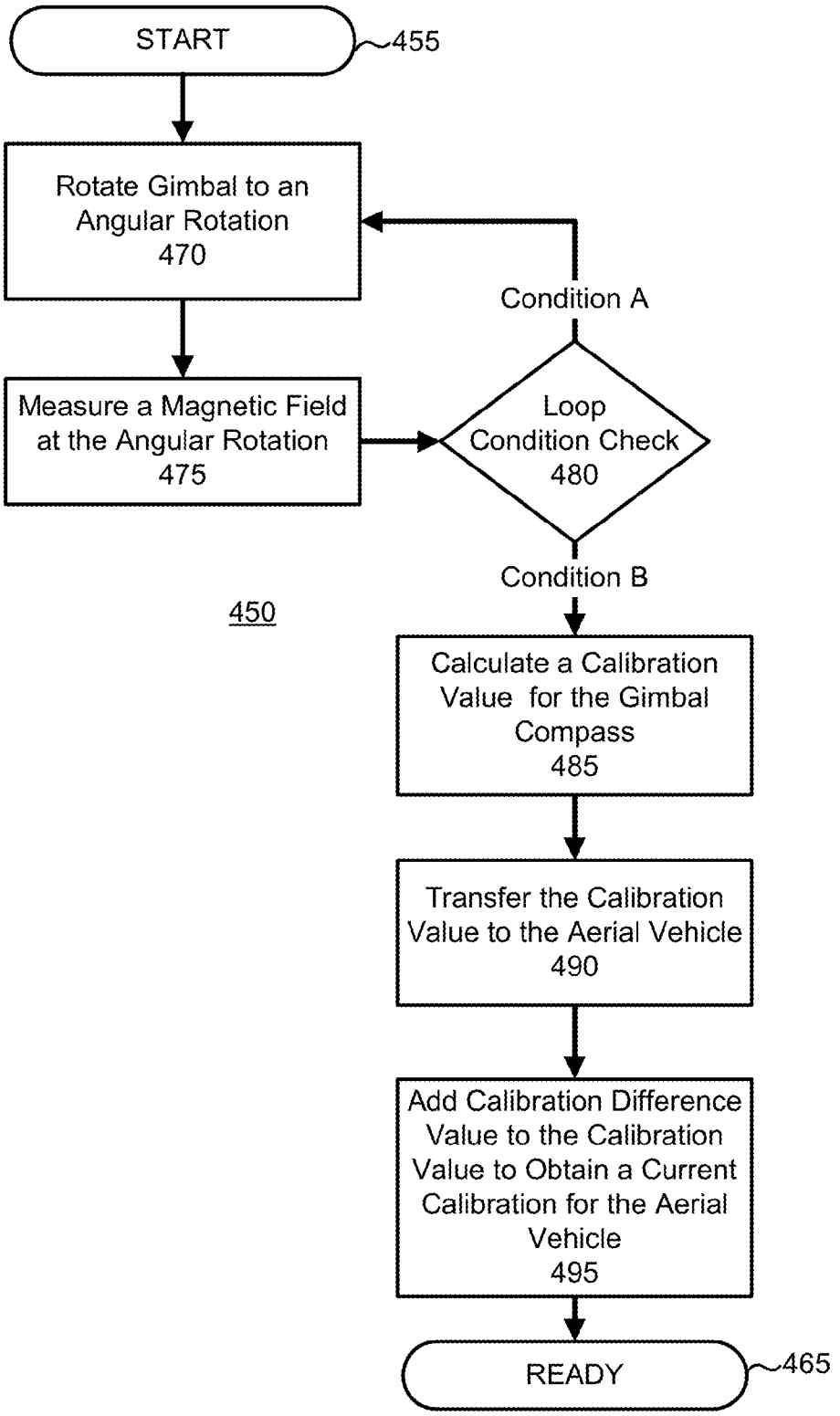

Prop 140
Thrust Motor 240
ESC 320
Flight Controller 315
Power Subsystem 340
Battery 440
LED 410
Antenna 460A
Antenna 460B
Video Link Controller 345
Sensor Subsystem 335
Compass 337
Communication Subsystem 360
Gimbal Interface 330
Gimbal Controller 420
Compass 425
Gimbal 210
Mounting Structure 475
Camera Interface Connectors 430
Camera 230
Camera Frame 220

FIG. 4A

FIG. 4B


START
455
Rotate Gimbal to an Angular Rotation 470
Measure a Magnetic Field at the Angular Rotation 475
Loop Condition Check 480
Condition A
Condition B
450
Calculate a Calibration Value for the Gimbal Compass 485
Transfer the Calibration Value to the Aerial Vehicle 490
Add Calibration Difference Value to the Calibration Value to Obtain a Current Calibration for the Aerial Vehicle 495
READY
465

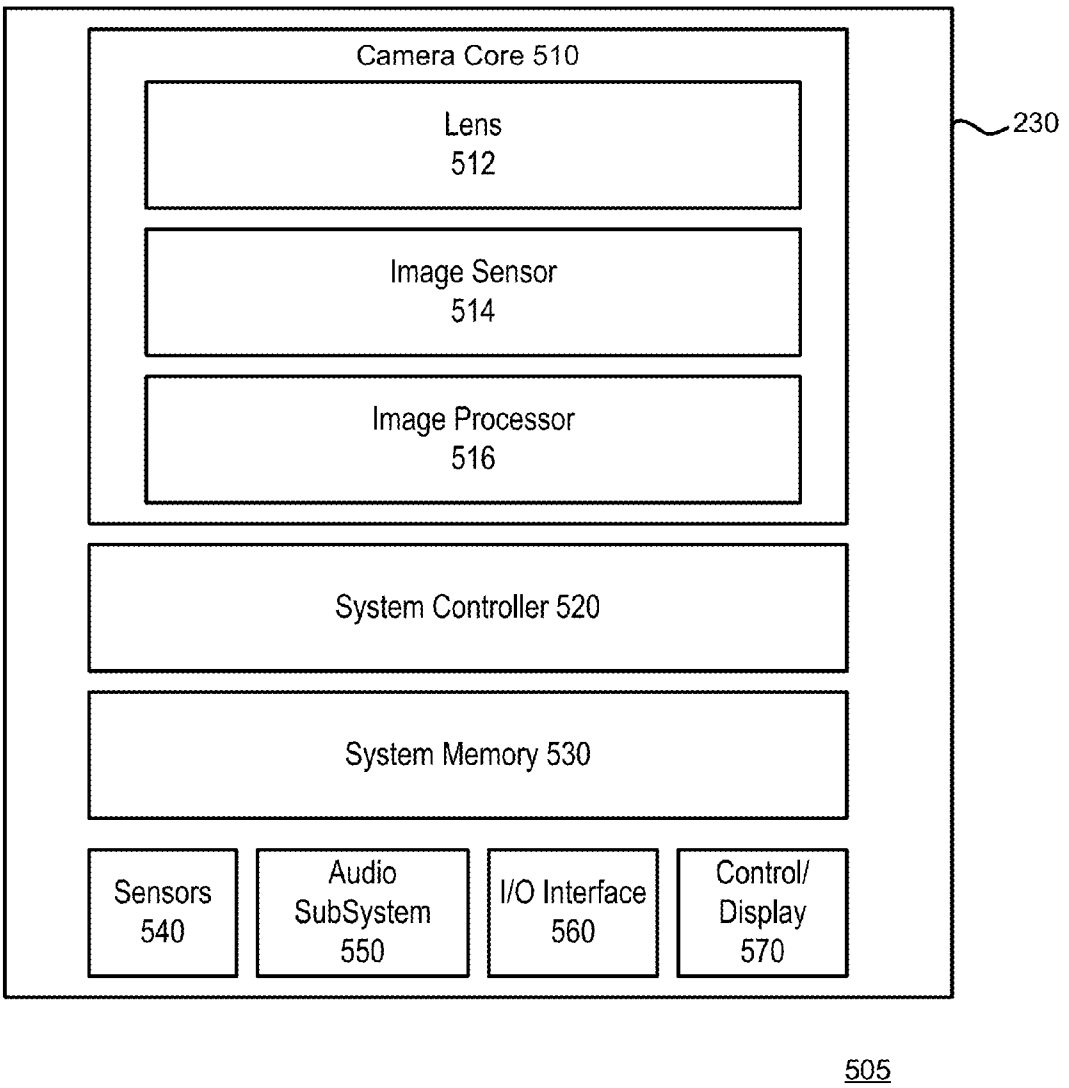

Camera Core 510
Lens
512
Image Sensor
514
Image Processor
516
System Controller 520
System Memory 530
Sensors
540
Audio
SubSystem
550
I/O Interface
560
Control/
Display
570
230
505

FIG. 5

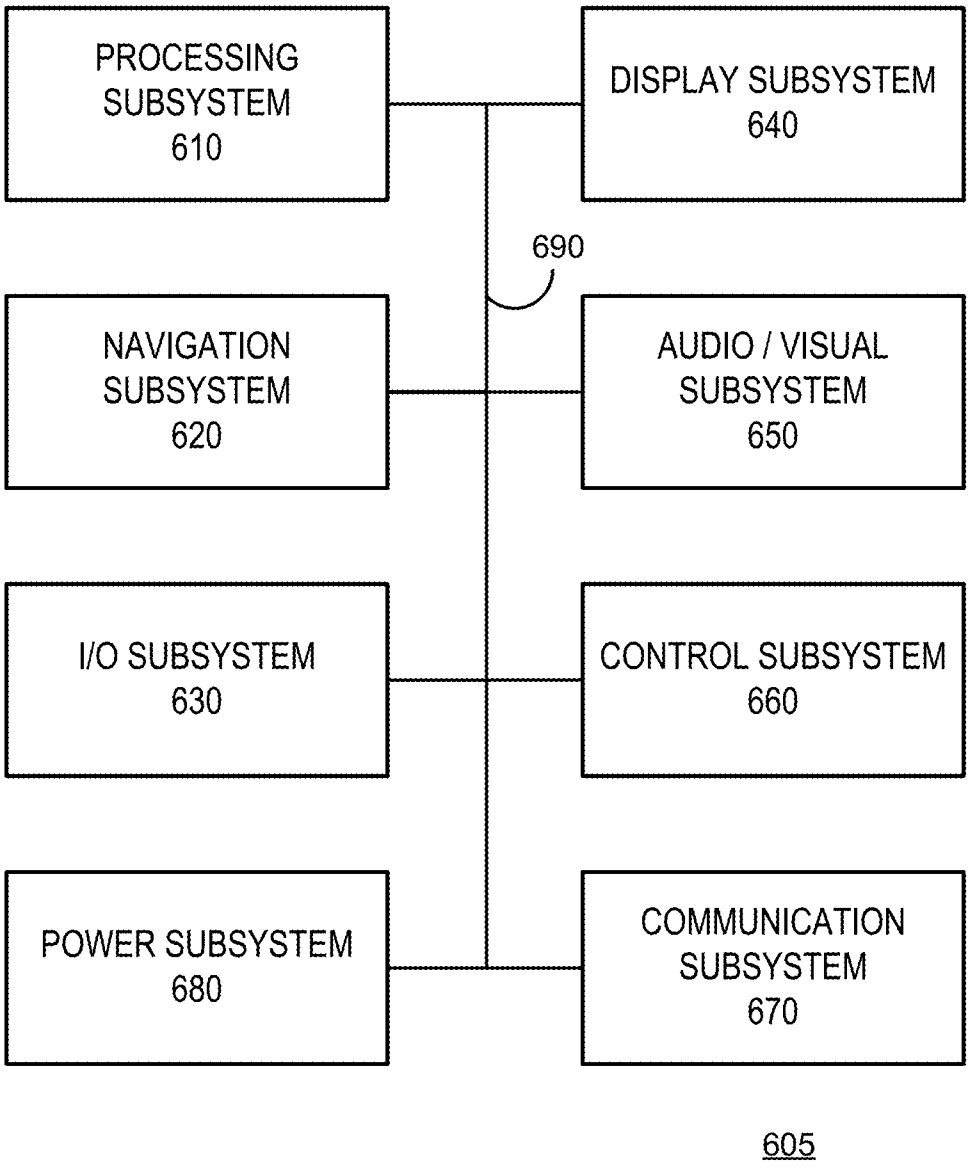

PROCESSING SUBSYSTEM 610
DISPLAY SUBSYSTEM 640
690
NAVIGATION SUBSYSTEM 620
AUDIO / VISUAL SUBSYSTEM 650
I/O SUBSYSTEM 630
CONTROL SUBSYSTEM 660
POWER SUBSYSTEM 680
COMMUNICATION SUBSYSTEM 670
605

FIG. 6

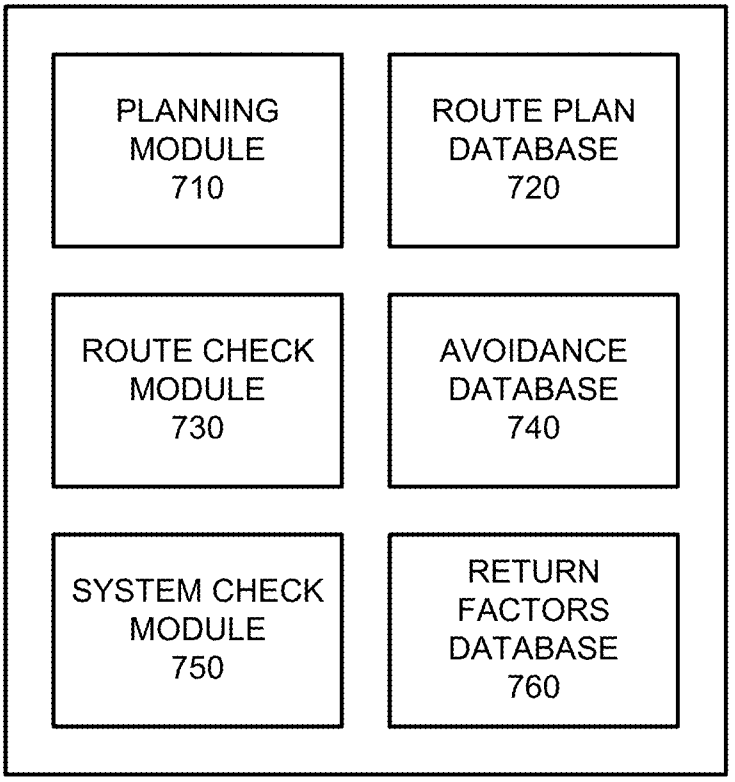

PLANNING MODULE 710
ROUTE PLAN DATABASE 720
ROUTE CHECK MODULE 730
AVOIDANCE DATABASE 740
SYSTEM CHECK MODULE 750
RETURN FACTORS DATABASE 760
705

FIG. 7

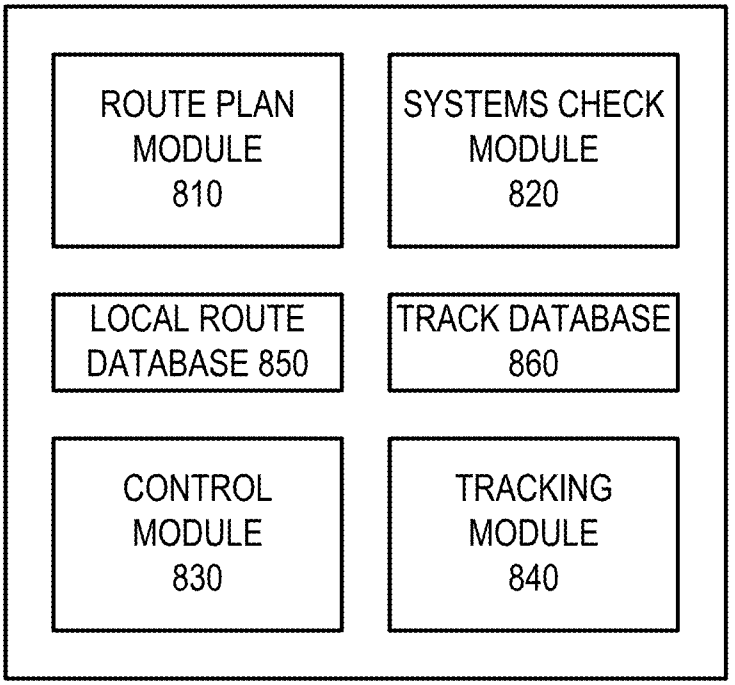

ROUTE PLAN MODULE 810
SYSTEMS CHECK MODULE 820
LOCAL ROUTE DATABASE 850
TRACK DATABASE 860
CONTROL MODULE 830
TRACKING MODULE 840
805

FIG. 8

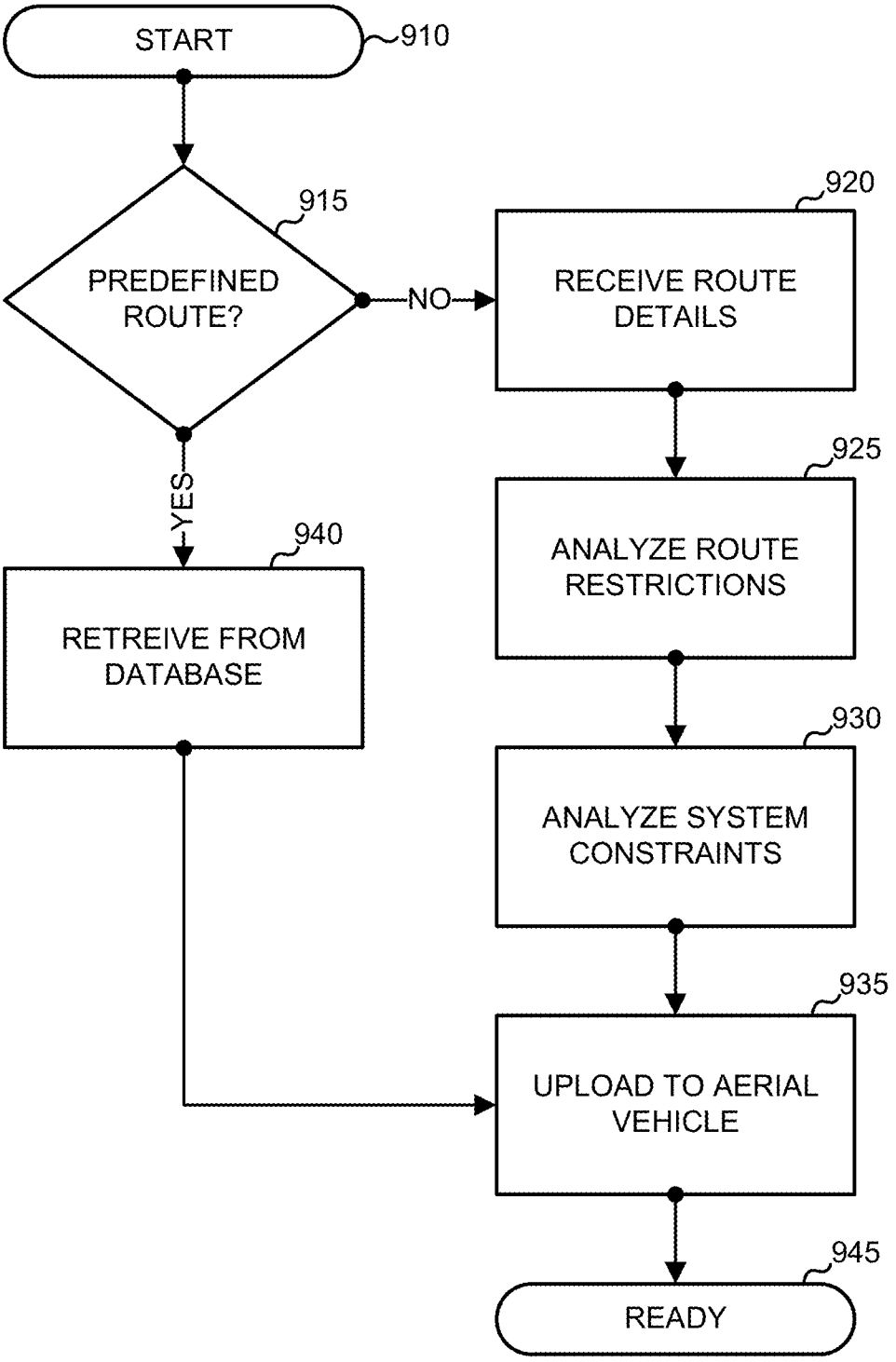

START
910
915
PREDEFINED ROUTE?
NO
YES
920
RECEIVE ROUTE DETAILS
925
ANALYZE ROUTE RESTRICTIONS
930
ANALYZE SYSTEM CONSTRAINTS
935
UPLOAD TO AERIAL VEHICLE
940
RETREIVE FROM DATABASE
945
READY

FIG. 9

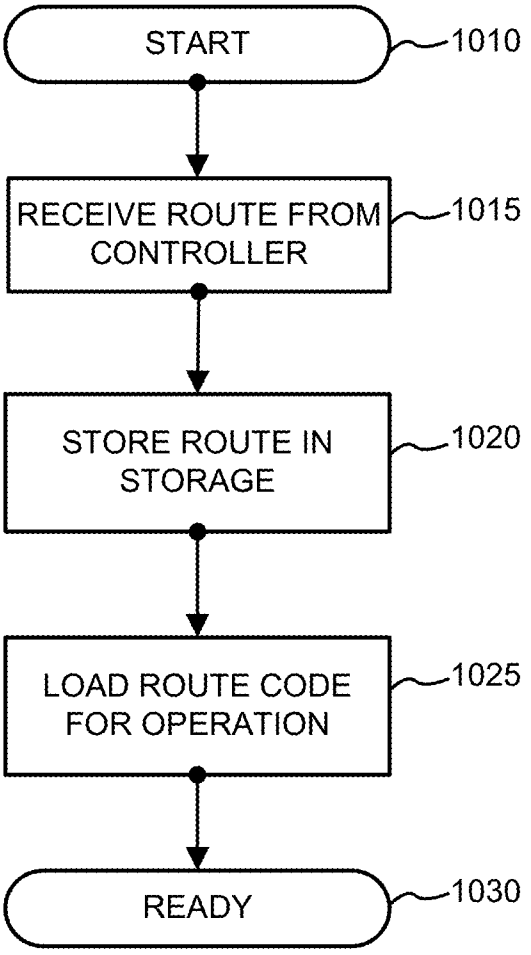

START
1010
RECEIVE ROUTE FROM CONTROLLER
1015
STORE ROUTE IN STORAGE
1020
LOAD ROUTE CODE FOR OPERATION
1025
READY
1030

FIG. 10

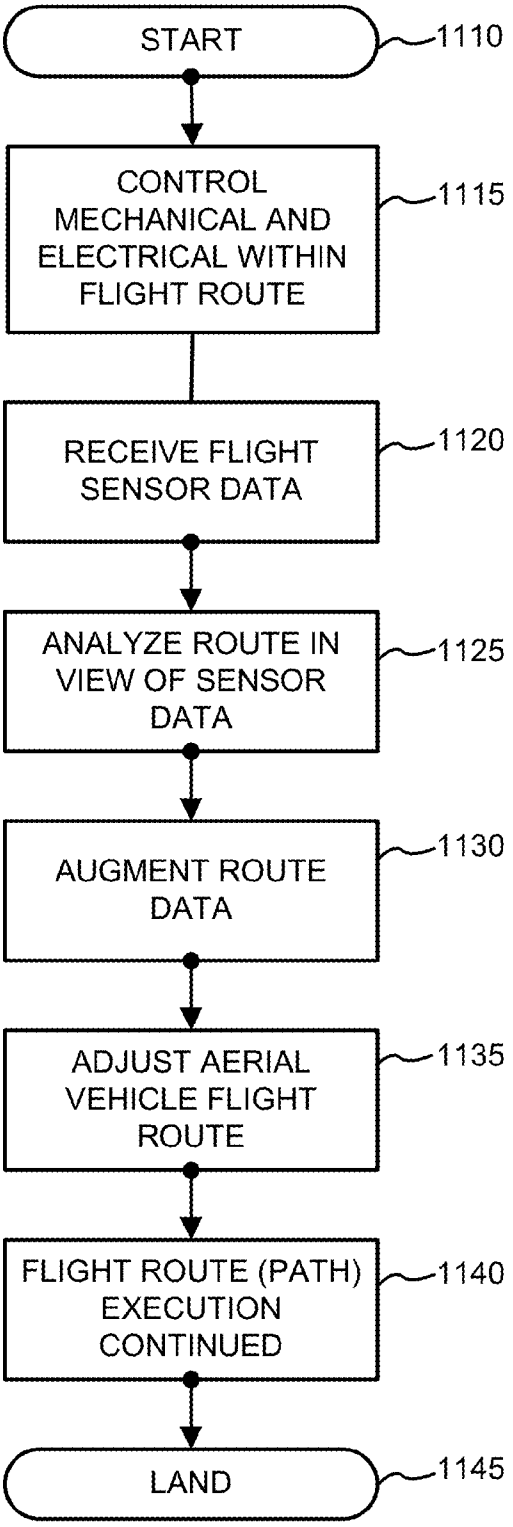

START
1110
CONTROL MECHANICAL AND ELECTRICAL WITHIN FLIGHT ROUTE
1115
RECEIVE FLIGHT SENSOR DATA
1120
ANALYZE ROUTE IN VIEW OF SENSOR DATA
1125
AUGMENT ROUTE DATA
1130
ADJUST AERIAL VEHICLE FLIGHT ROUTE
1135
FLIGHT ROUTE (PATH) EXECUTION CONTINUED
1140
LAND
1145

FIG. 11

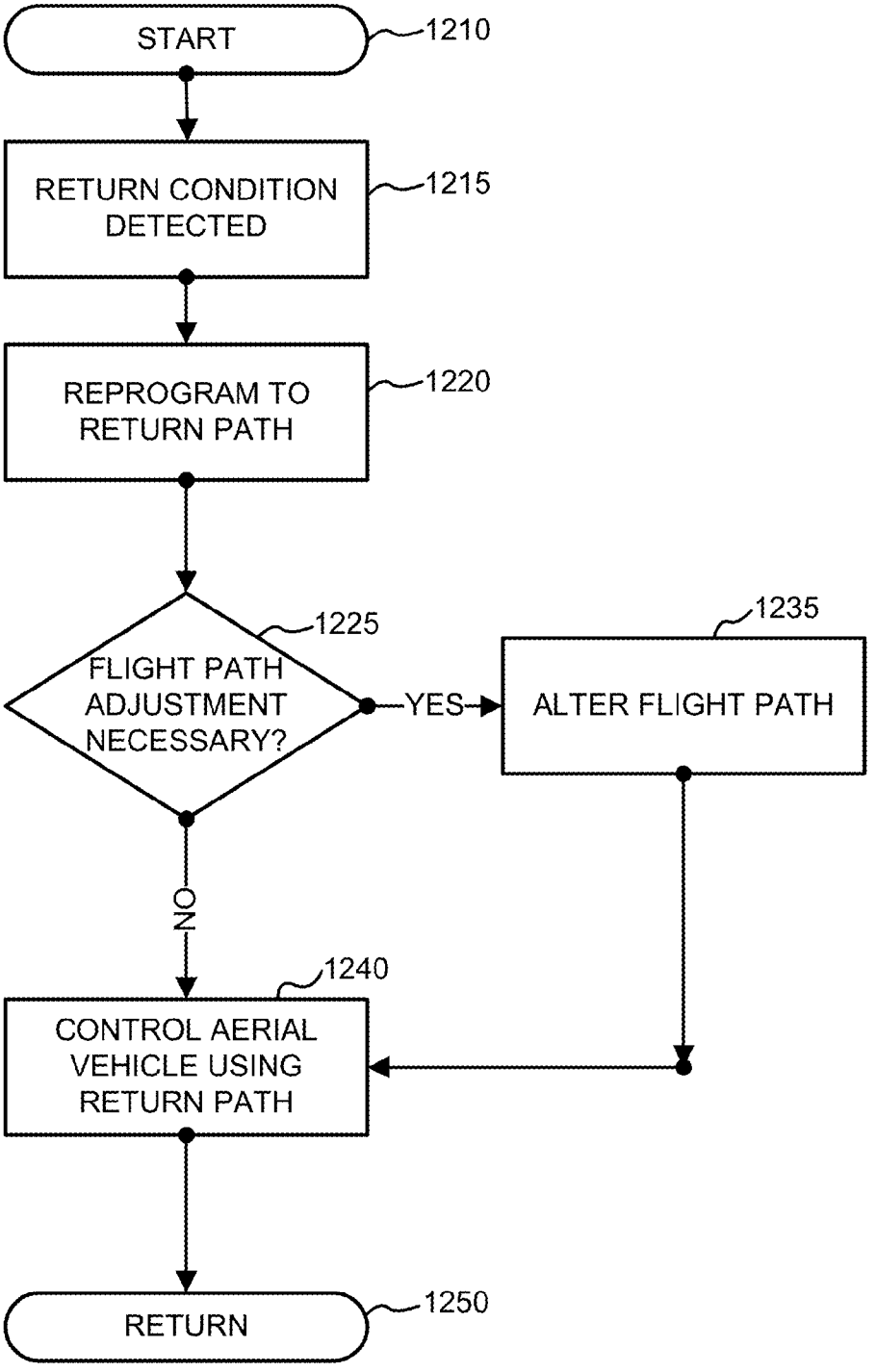
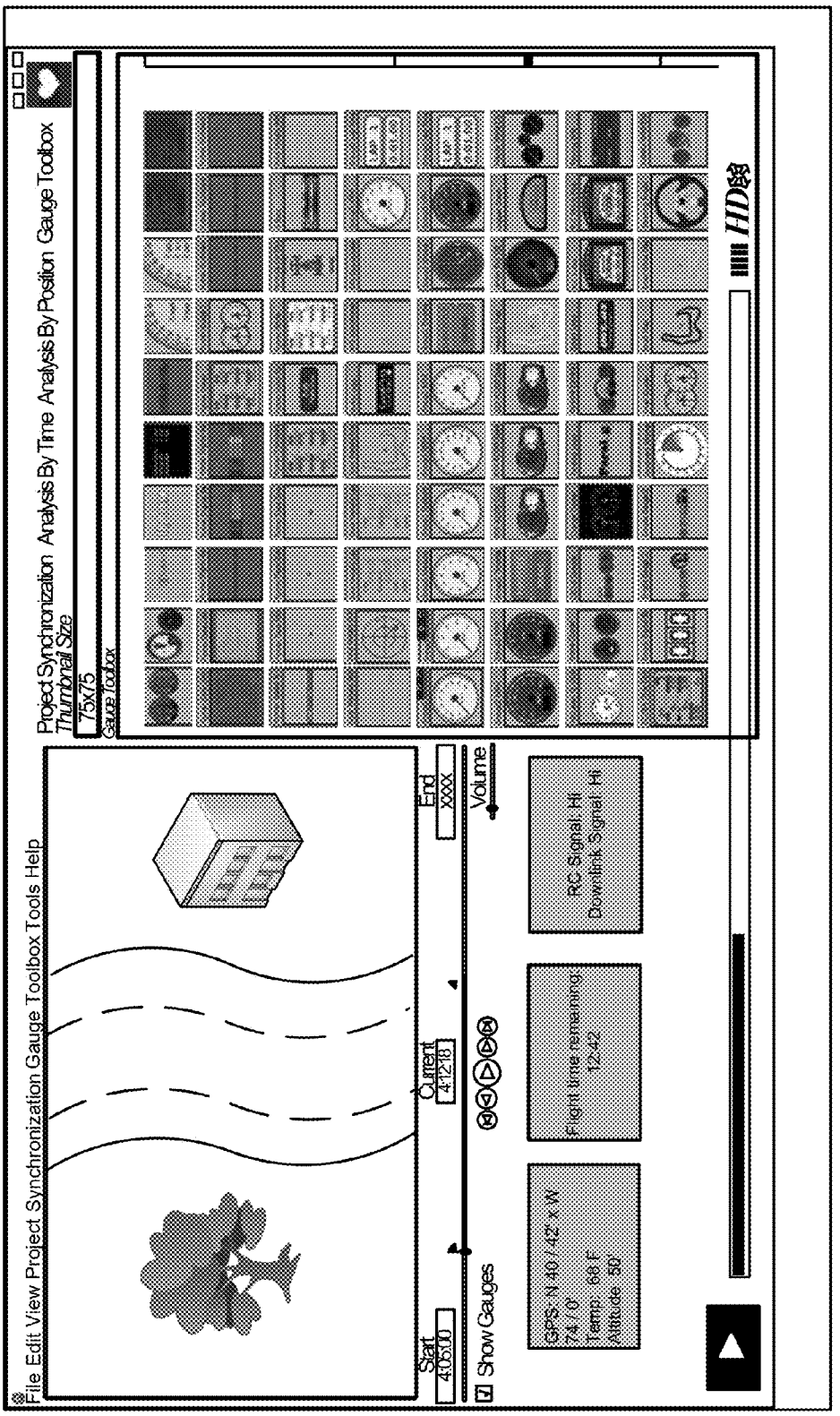

START
1210
RETURN CONDITION DETECTED
1215
REPROGRAM TO RETURN PATH
1220
FLIGHT PATH ADJUSTMENT NECESSARY?
1225
YES
ALTER FLIGHT PATH
1235
NO
CONTROL AERIAL VEHICLE USING RETURN PATH
1240
RETURN
1250

FIG. 12


File Edit View Project Synchronization Gauge Toolbox Tools Help
Project Synchronization Analysis By Time Analysis By Position Gauge Toolbox
Thumbnail Size
75x75
Gauge Toolbox
Start
4:06:00
Current
4:12:18
End
xxxx
Volume
Show Gauges
GPS: N 40 / 42' x W
74 / 0'
Temp: 66 F
Altitude: 59'
Flight time remaining
12:42
RC Signal: Hi
Downlink Signal: Hi
HD

1305

FIG. 13

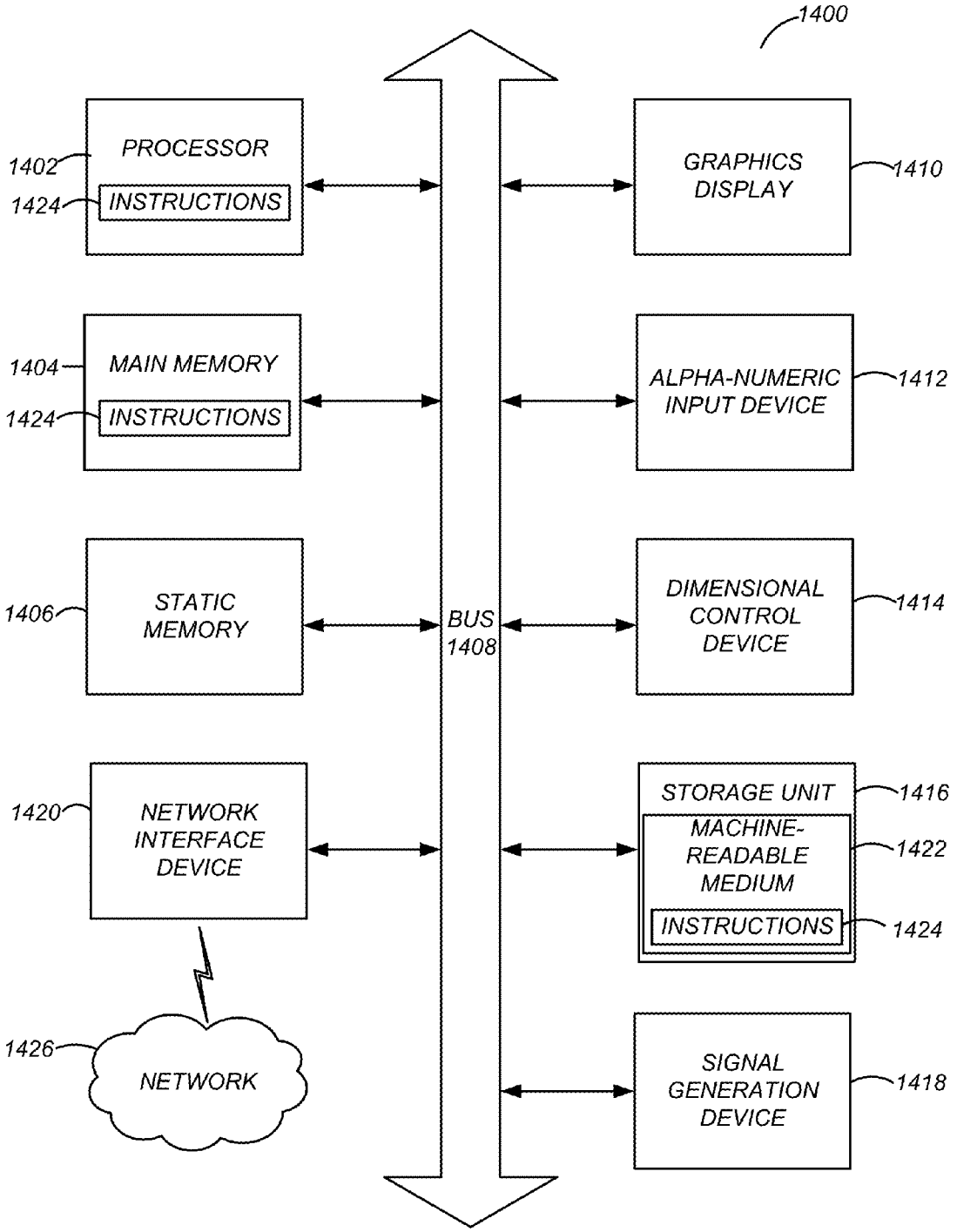

1400
PROCESSOR
1402
INSTRUCTIONS
1424
MAIN MEMORY
1404
INSTRUCTIONS
1424
STATIC MEMORY
1406
NETWORK INTERFACE DEVICE
1420
NETWORK
1426
BUS
1408
GRAPHICS DISPLAY
1410
ALPHA-NUMERIC INPUT DEVICE
1412
DIMENSIONAL CONTROL DEVICE
1414
STORAGE UNIT
1416
MACHINE-READABLE MEDIUM
1422
INSTRUCTIONS
1424
SIGNAL GENERATION DEVICE
1418

FIG. 14

CALIBRATION TRANSFER BETWEEN TWO DEVICES

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Patent Application No. 62/157,877, filed May 6, 2015, the contents of which are incorporated by reference in its entirety.

BACKGROUND

[0002] 1. Field of Art

[0003] The disclosure generally relates to compasses and in particular to automatically calibrating a compass in an aerial vehicle based on the calibration of the compass in a gimbal.

[0004] 2. Description of Art

[0005] Remote controlled devices with image capture devices (e.g., cameras and/or video cameras) mounted upon those devices are well known. For example, a remote control road vehicle can be configured to mount an image capture device on it to capture images as the vehicle is moved about remotely by a user. Similarly, remote controlled aerial vehicles, e.g., quadcopters, have been mounted with image capture devices to capture aerial as a user remotely controls the vehicle.

[0006] An issue with flying aerial vehicles is a lack of compass calibration. A miscalibrated magnetometer in a compass may be a cause of vehicle disorientations when flying the aerial vehicle. Hence, calibration is recommended before flight if the aerial vehicle was transported to an area with a different magnetic field. Despite this recommendation, magnetometer compass calibration is commonly forgotten. Moreover, when it is remembered, the calibration process is not a user-friendly process. It requires the user to manipulate the entire platform, i.e., the entire aerial vehicle, in a wide range of motion. This may be a time consuming and cumbersome process, which may cause users to ultimately skip the process or at least not perform it thoroughly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The disclosed embodiments have advantages and features which will be more readily apparent from the detailed description, the appended claims, and the accompanying figures (or drawings). A brief introduction of the figures is below.

[0008] FIG. **1** illustrates an example configuration of remote controlled aerial vehicle in communication with a remote controller.

[0009] FIG. **2** illustrates an example of a remote controlled aerial vehicle.

[0010] FIG. **3** illustrates an example of a remote controlled aerial vehicle electronics and control systems.

[0011] FIG. **4**A illustrates an example interconnect architecture of a remote controlled aerial vehicle with a gimbal.

[0012] FIG. **4**B illustrates a flow diagram for an example automatic compass calibration process.

[0013] FIG. **5** illustrates a block diagram of an example camera architecture.

[0014] FIG. **6** illustrates a block diagram of an example remote control system of a remote controller.

[0015] FIG. **7** illustrates a functional block diagram of an example flight plan control system for a remote controller.

[0016] FIG. **8** illustrates a functional block diagram of an example flight plan control system for a remote controlled aerial vehicle.

[0017] FIG. **9** illustrates a flow diagram for an example program path operation on a remote controller.

[0018] FIG. **10** illustrates a flow diagram for an example program path operation load on a remote controlled aerial vehicle.

[0019] FIG. **11** illustrates a flow diagram for an example program path operation on a remote controlled aerial vehicle.

[0020] FIG. **12** illustrates a flow diagram for an example return path operation on a remote controlled aerial vehicle.

[0021] FIG. **13** illustrates an example user interface for a remote controller.

[0022] FIG. **14** illustrates an example machine for use with a system of the remote controlled aerial vehicle.

DETAILED DESCRIPTION

[0023] The Figures (FIGS.) and the following description relate to preferred embodiments by way of illustration only. It should be noted that from the following discussion, alternative embodiments of the structures and methods disclosed herein will be readily recognized as viable alternatives that may be employed without departing from the principles of what is claimed.

[0024] Reference will now be made in detail to several embodiments, examples of which are illustrated in the accompanying figures. It is noted that wherever practicable similar or like reference numbers may be used in the figures and may indicate similar or like functionality. The figures depict embodiments of the disclosed system (or method) for purposes of illustration only. One skilled in the art will readily recognize from the following description that alternative embodiments of the structures and methods illustrated herein may be employed without departing from the principles described herein.

Configuration Overview

[0025] Disclosed by way of example embodiments is a remote controlled aerial vehicle with camera and mounting configuration. The remote controlled aerial vehicle may include a mounting structure that secures an image capture device. The mounting structure may be removably attachable with an aerial vehicle. Moreover, the image capture device may be configured so that it may be removably attachable from the mounting structure. The mounting structure when removed from the aerial vehicle also can operate as a standalone mount.

[0026] In one embodiment, the mounting structure may include a mounting structure that may include a three-axis gimbal (for roll, pitch and yaw motion). An image capture device couples with this gimbal. When coupled with an image capture device, the gimbal may be capable of rotating the camera in all directions. The gimbal also may be capable of precisely measuring angles. The gimbal may include a compass with one or more magnetometers. In addition, the gimbal base may include an inertial measurement unit (IMU) sensor. The aerial vehicle may also include an IMU sensor. When coupled with the aerial vehicle, the gimbal may be configured to transfer magnetometer calibration values from the gimbal to the aerial vehicle.

[0027] Also disclosed is a configuration for a remote controlled aerial vehicle to have a route (e.g., a flight path) programmed into the remote controlled aerial vehicle and then executed during operation of the vehicle. In operation, the vehicle may monitor operational, mechanical, and environmental configurations to determine whether the vehicle can continue on the route, make adjustments or return to a predefined location. This configuration may include automating the process of flight adjustments and returns so that the remote controlled aerial vehicle may be able to operate with minimal to no impact on its immediate surroundings. Moreover, the return flight path benefits from the properly calibrated compass on the aerial vehicle. For example, if a condition detected by the aerial vehicle triggers it to automatically return via execution of a return path program, the aerial vehicle may rely on its now automated guidance system (which includes the properly calibrated magnetometer compass) to follow the specific return path programmed without need for having human intervention to make course adjustments, e.g., relating to directionality.

Example System Configuration

[0028] Turning now to FIG. **1**, it illustrates an example configuration **100** of a remote controlled aerial vehicle **110** in communication with a remote controller **120**. The configuration **100** includes a remote controlled aerial vehicle ("aerial vehicle") **110** and a remote controller **120**. The aerial vehicle **110** and the remote controller **120** may be communicatively coupled through a wireless link **125**. The wireless link may be a wireless local area network (e.g., Wi-Fi), cellular (e.g., long term evolution (LTE), 3G, 4G, 5G), and/or other wireless communication link. The aerial vehicle **110** may be, for example, a quadcopter or other multirotor helicopter.

[0029] The aerial vehicle **110** in this example may include a housing **130** for a payload (e.g., electronics, storage media, and/or camera), two or more arms **135**, and two or more propellers **140**. Each arm **135** may mechanically couple with a respective thrust motor that couples a propeller **140** to create a rotary assembly. When the rotary assembly is operational, the propellers **140** spin at appropriate speeds and directions to allow the aerial vehicle **110** to lift (take off), land, hover, and move (forward, backward) in flight.

[0030] The remote controller **120** in this example includes a first control panel **150** and a second control panel **155**, an ignition button **160**, a return button **165** and a screen **170**. A first control panel, e.g., **150**, may be used to control "up-down" direction (e.g. lift and landing) of the aerial vehicle **110**. A second control panel, e.g., **155**, may be used to control "forward-reverse" direction of the aerial vehicle **110**. Each control panel **150**, **155** may be structurally configured as a joystick controller and/or touch pad controller. The ignition button **160** may be used to start the rotary assembly (e.g., start the respective thrust motors coupled with the propellers **140**). The return (or come home) button **165** may be used to override the controls of the remote controller **120** and transmit instructions to the aerial vehicle **110** to return to a predefined location as further described herein. The ignition button **160** and the return button **165** may be mechanical and/or solid state press sensitive buttons. In addition, each button may be illuminated with one or more light emitting diodes (LED) to provide additional details. For example, an LED of the ignition button **160** may switch from one visual state to another to indicate whether the aerial vehicle **110** is ready to fly (e.g., lit green) or not (e.g., lit red). Also, an LED of the return button **165** may switch between visual states to indicate whether the aerial vehicle **110** is now in an override mode on return path (e.g., lit yellow) or not (e.g., lit red). It also is noted that the remote controller **120** may include other dedicated hardware buttons and switches and those buttons and switches may be solid state buttons and switches.

[0031] The remote controller **120** may also include a screen (or display) **170**. The screen **170** may provide for visual display. The screen **170** may be a touch sensitive screen. The screen **170** also may be, for example, a liquid crystal display (LCD), an LED display, an organic LED (OLED) display, and/or a plasma screen. The screen **170** may allow for display of information related to the remote controller **120**, such as menus for configuring the remote controller **120** and/or remotely configuring the aerial vehicle **110**. The screen **170** also may display images captured from an image capture device coupled with the aerial vehicle **110**.

Remote Controlled Aerial Vehicle

[0032] Referring now to FIG. **2**, it illustrates an example embodiment of the remote controlled aerial vehicle **110**. The remote controlled aerial vehicle **110** in this example is shown with the housing **130** and arms **135** of the arm assembly. In addition, this example embodiment shows a thrust motor **240** coupled with the end of each arm **130** of the arm assembly, a gimbal **210**, a camera frame **220**, and a camera **230**. The thrust motor **240** couples with the propellers **140** to spin the propellers **140** when the thrust motors **240** are operational.

[0033] The gimbal **210** may be configured to allow for rotation of an object about an axis. The gimbal **210** may be a 3-axis gimbal **210** with three motors, each corresponding to a respective axis. Here, the object that the gimbal **210** rotates is a camera **230** coupled to camera frame **220** to which the gimbal **210** is mechanically coupled. The gimbal **210** and the camera frame **220** may form a mounting structure and when coupled together the entire assembly may be referenced as a gimbal **210** for ease of discussion. The camera frame **220** may be configured to allow the camera **230** to detachably couple (e.g., attach) to it and may include electrical connection points for the coupled camera **230**. The gimbal **210** may allow for the camera frame **220** to maintain a particular position and/or orientation so that the camera **230** mounted to it can remain steady as the aerial vehicle **110** is in flight. In some embodiments, the camera frame **220** may be integrated into the gimbal **210** as a camera mount. In some embodiments, the camera frame **220** may be omitted and the gimbal **210** couples electronically and mechanically to the camera **230**.

[0034] FIG. **3** illustrates an example embodiment of an electronics and control (EC) system **310** of the aerial vehicle **110**. The EC system **310** may include a flight controller **315**, an electronic speed controller **320**, one or more thrust motors **240**, a gimbal interface **330**, a sensor (or telemetric) subsystem **335**, a power subsystem **340**, a video link controller **345**, a camera interface **350**, and a communication subsystem **360**. The components may communicate directly or indirectly with each other through a data bus on the aerial vehicle **110**.

[0035] In one embodiment, the communication subsystem **360** may be a long-range Wi-Fi system. It also may include or be another wireless communication system, for example,

one based on long term evolution (LTE), 3G, 4G, and/or 5G mobile communication standards. The communication subsystem **360** also may be configured with a unidirectional RC channel for communication of controls from the remote controller **120** to the aerial vehicle **110** and a separate unidirectional channel for video downlink from the aerial vehicle **110** to the remote controller **120** (or to a video receiver where direct video connection may be desired). The sensor subsystem **335** may include navigational components, for example, a gyroscope, accelerometer, a global positioning system (GPS) and/or a barometric sensor. The telemetric compass may also include an unmanned aerial vehicle (UAV) compass **337**. The UAV compass **337** may include one or more magnetometer sensors with which it determines the orientation of the aerial vehicle **110**. The power subsystem **340** may include a battery pack and/or a protection circuit module as well as a power control and/or battery management system. The camera interface **350** may interface with an image capture device (e.g., camera **230**) or may include an integrated image capture device. The integrated image capture device may be positioned similarly to the camera frame **220**.

[0036] The flight controller **315** of the EC system **310** may communicate with the remote controller **120** through the communication subsystem **360**. The flight controller **315** may control the flight related operations of the aerial vehicle **110** by controlling the other components such as the electronic speed controller **320** and/or the sensor subsystem **335**. The flight controller **315** may interface with the gimbal control **420** to control the gimbal **210**. The flight controller may interface with the gimbal controller **420** of the gimbal **210** through the gimbal interface **330**. The flight controller **315** also may interface with the video link controller **345** for operation control of an image capture device (e.g., camera **230**) coupled to the aerial vehicle **110**.

[0037] The electronic speed controller **320** may be configured to interface with the thrust motors **240** (via electronics interface) to control the speed and thrust applied to the propellers **140** of the aerial vehicle **110**. The video link controller **345** may be configured to communicate with the camera interface **350** to capture and transmit images from an image capture device to the remote controller **120** (or other device with a screen such as a smart phone), e.g., via the communication subsystem **360**. The video may be overlaid and/or augmented with other data from the aerial vehicle **110** such as the telemetric (or sensor) data from the sensor subsystem **335**. The power subsystem **340** may be configured to manage and supply power each of the components of the EC system **310**.

[0038] Turning to FIG. **4**A, it illustrates an example interconnect architecture of the aerial vehicle **110** with the gimbal **210**. This example embodiment may include the components illustrated and described in the prior figures, e.g., FIG. **3**. Also shown are such as LEDs **410** on the aerial vehicle **110** that may be used to provide vehicle status related information. Also shown is a battery **440** as a part of the power subsystem **340** and two antennas **460**A-**460**B as a part of the communication subsystem **360**.

[0039] The figure illustrates in an example embodiment that the flight controller **315** may be coupled with two electronic speed controllers **320**. Each electronic speed controller **320** in this configuration may drive two thrust motors **240** (via respective components of each thrust motor).

[0040] Also shown is a gimbal interface **330** that may communicatively couple the gimbal controller **420** to components of the EC system **310**. In particular, the gimbal interface **330** may be communicatively coupled with the video link controller **345**, the sensor subsystem **335** (e.g., the GPS and/or the compass), and/or one or more of the antennas **460**A-**460**B. The gimbal interface **330** may be used to feed data (e.g., telemetric data, control signals received from the remote controller **120**, and/or video link control signals) from the video link controller **345**, the sensor subsystem **335**, and/or one or more of the antennas **460**A-**460**B to the gimbal controller **420**. The gimbal controller **420** may use this data to adjust the camera frame **220**. It is noted that the camera frame **220** may be, for example, a camera holder frame to secure a camera **230**. The gimbal controller **420** may be communicative coupled with the camera **230** through one or more camera interface connectors **430**. The camera interface connectors **430** may include camera communication interfaces such as universal serial bus (USB) and/or HDMI. The media captured by the camera **230** (e.g., still images, video, and/or audio) may be communicated to the aerial vehicle **110** through the camera interface connectors **430**. Data (e.g., telemetric data from the sensor subsystem **335**) also may be sent via the camera interface connectors **430** to the camera **230** to associate with video captured and stored on the camera **230**.

[0041] In some embodiments, the gimbal interface **330** may perform functions attributed herein to the gimbal controller **420**. For example, the gimbal interface **330** may set a position for each motor in the gimbal **210** and/or determine a current position for each motor of the gimbal **210** based on signals received from one or more rotary encoders.

Automatic Compass Calibration

[0042] In one example aspect, the remote controlled aerial vehicle **110** includes a mounting structure **475**. In one example embodiment, the mounting structure **475** may be removably attachable with the aerial vehicle **110** and may be structured to operate as a standalone mount. Continuing with the example embodiment, the mounting structure **475** may include a three-axis gimbal (e.g., gimbal **210**) and a camera frame **220**. The three-axis (e.g., x, y, and z axis) gimbal (e.g., gimbal **210**) may include the gimbal controller **420**, a gimbal compass **425**, and/or an inertial measurement unit (IMU) sensor. The camera frame **220** may secure a camera, e.g., the camera **230**.

[0043] When a camera (e.g., camera **230**) couples with the mounting structure **475**, the gimbal controller **420** may be able to rotate the attached camera **230** in all directions. The gimbal controller **420** may be capable of precisely measuring rotational angles (e.g., roll, pitch and yaw). The gimbal **210** may include a gimbal compass **425** (e.g., a compass with one or more magnetometer sensors). The aerial vehicle **110** also may include a UAV compass **337** and/or an IMU sensor. When coupled with the aerial vehicle **110**, the gimbal compass **425** and the UAV compass **337** may interact for calibration. An IMU in the gimbal **210** and an IMU in the aerial vehicle **110** may also interact for calibration of the UAV compass **337**.

[0044] It is noted that in an alternate aspect, the gimbal **210** may use rotary encoders (rotary encoders are, for example, conductive, optical, and/or magnetic) in addition to, or rather than, an IMU sensor. For example, when coupled with the aerial vehicle **110**, readings from the

gimbal compass **425**, IMU, and/or rotary encoders from gimbal axes may be compared with UAV compass **337** and IMU readings of the aerial vehicle **110** for calibration as further described below.

[0045] The gimbal compass **425** and the UAV compass **337** may each include a respective magnetometer that can measure magnetic field in three dimensions. Values read from a magnetometer may be represented as (M_x, M_y, M_z). When rotated in all directions, magnetometer measurements ideally describe a sphere centered at (0, 0, 0). That is, suppose a compass is placed in a constant magnetic field but is otherwise not in the presence of interference. If the magnetic field at the location of the compass is represented by a polar coordinate vector B=(||B||, θ, ϕ) where ||B|| is the magnitude of the magnetic field (e.g., in Tesla) and θ and ϕ are angles specifying the direction of the field (e.g., 0°≤θ, ϕ<360°), then the compass, when rotated to any orientation (θ', ϕ), will measure a magnetic field of B'=(||B||, θ+θ', ϕ+ϕ'). Thus, the compass, when rotated to every direction, may measure a "sphere" centered (0,0,0) in Cartesian coordinates with a radius of ||B||.

[0046] Compasses (e.g., the gimbal compass **425** and/or the UAV compass **337**) may be calibrated for hard-iron and/or soft-iron interference. Hard-iron interference may be caused by permanent magnets or magnetized iron/steel that are in the vicinity of the magnetometer of a compass. Hard-iron interference may be caused be external sources. Hard-iron interference may shift the center of the sphere described by (M_x, M_y, M_z) measurements away from (0, 0, 0). Soft-iron interference may be caused by internal factors such as current carrying traces on a printed circuit board (PCB) that includes the magnetometer. Soft-iron interference distorts the sphere where full round rotation circles have ellipsoidal shape.

[0047] The relationship between the normalized (calibrated) values (M_{xn}, M_{yn}, M_{zn}) and raw sensor measurements (M_x, M_y, M_z) may be expressed as follows:

$$\begin{bmatrix} M_{xn} \\ M_{yn} \\ M_{zn} \end{bmatrix} = [M_m]_{3\times3} \begin{bmatrix} \frac{1}{M_{scx}} & 0 & 0 \\ 0 & \frac{1}{M_{scy}} & 0 \\ 0 & 0 & \frac{1}{M_{scz}} \end{bmatrix} [M_{si}]_{3\times3} \begin{bmatrix} M_x - M_{osx} \\ M_y - M_{osy} \\ M_z - M_{osz} \end{bmatrix}$$

$$= \begin{bmatrix} MR_{11} & MR_{12} & MR_{13} \\ MR_{21} & MR_{22} & MR_{23} \\ MR_{31} & MR_{32} & MR_{33} \end{bmatrix} \begin{bmatrix} M_x - MR_{10} \\ M_y - MR_{20} \\ M_z - MR_{30} \end{bmatrix}$$

Here, M_{sck} may be scale factors, M_{osk} are offsets for hard-iron distortion, and M_{sk} may be a matrix that describes soft-iron distortion (k being x, y, or z). In one example aspect, a goal of compass calibration may be to describe MR_{10} to MR_{33} so that normalized values may be obtained from raw measurements. It is noted that an aerial vehicle may be designed to minimize soft-iron interference by placing magnetometers away from potential magnetic sources. Hence, the compasses may be calibrated for hard-iron interference using least squares sphere fitting based on a couple hundred measurements.

[0048] Continuing with a calibration process of the compass, in one example embodiment, magnetometer compass values may be initially factory calibrated. Factory calibration may involve mechanically locking two devices, e.g., the gimbal **210** (or mounting structure **475**) and the aerial vehicle **110**, and calibrating the compasses in a magnetically neutral environment. Both devices (e.g., the gimbal **210** and the aerial vehicle **110**) may be taken through a wide range of motion during factory calibration. Once both devices are calibrated, the difference in calibration values between the two devices may be stored, e.g., in a memory storage of the aerial vehicle **110**.

[0049] It is noted that a manual calibration step, similar to the factory calibration, may be needed after crashes and when self-checks fail. An automatic pre-flight check may be configured to detect calibration issues by comparing outputs of two or more magnetometer readings. A magnetometer on the gimbal **210** may be fixed in relation to a frame of the aerial vehicle **110** by manually setting all gimbal axes to the extreme angle (e.g., pushing them to hard stops).

[0050] When the aerial vehicle **110** is readied for flight, it may run an automated calibration process. For example, the aerial vehicle **110** coupled with the gimbal **210** may be placed at rest on a flat surface, e.g., flat ground. The gimbal **210** (or mounting structure **475**) may undergo a wide range of angular motion (e.g., roll, pitch, and/or yaw rotation) via its axis motors controlled via the gimbal controller **420**. These motions may be used to calibrate the gimbal compass **425**. Once the gimbal compass **425** is calibrated, the calibration value may be copied (or transferred) over to the aerial vehicle **110**. The aerial vehicle **110** may add in the previously stored calibration difference value from the factory calibration to obtain an adjusted calibration. The adjusted calibration may be saved in a storage, e.g., flash memory, in the aerial vehicle **110** as a current calibration value. The current calibration value may be used to operate the UAV compass **337**.

[0051] As an additional check, the gimbal **210** may be automatically commanded to orient in such a way that gimbal compass **425** is aligned with the UAV compass **337**. The values detected by the magnetometers (e.g., geographic directions, magnetic field directions, and/or magnetic field strengths) of the UAV and gimbal compasses **337**, **425** may be directly compared to check if they match. A mismatch may provide an indication of a bad calibration. In such circumstances, a full manual calibration may be requested (e.g., by displaying an indication to a user on the screen **170** of the remote controller **120**) to calculate new differences between the sensors.

[0052] By way of an example process, automatic calibration of the magnetometer compass may begin with a user powering up the aerial vehicle **110**. Once powered, the gimbal **210** may rotate in a wide range of motion. The gimbal **210** may calibrate its internal gimbal compass **425**. The aerial vehicle **110** may then receive calibration information from the gimbal **210** and may add in the pre-calculated difference obtained from the factory calibration value (i.e., the factory-defined calibration value). The aerial vehicle **110** may store the new calibration values in a storage, e.g., flash memory. The UAV compass **337** may now be considered calibrated for flight. The gimbal **210** may provide additional confirmation checks to ensure that the gimbal compass **425** of the gimbal **210** and/or the UAV compass **337** of the aerial vehicle **110** are aligned. Optionally, the aerial vehicle **110** may receive value associated with the alignment of the sensors of the UAV and gimbal compasses **337**, **425** to compare against a previously saved value

corresponding to the alignment for further confirmation that the calibration is correct. If the calibration is determined to not be correct, the aerial vehicle **110** may take further corrective action. In addition, the system may be configured to allow a user to check proper calibration through status information transmitted from the aerial vehicle **110** to the remote controller **120** for display on its screen **170** or by visual indicators, e.g., LED lights, on the aerial vehicle **110** and/or the remote controller **120**.

[0053] Using the automatic compass calibration configuration described, an aerial vehicle **110** may be calibrated with minimal user effort. Unlike conventional configurations, the aerial vehicle **110** may not need to force a user to work through a wide range of motions in order to calibrate its compass at startup. Rather, the gimbal (e.g., gimbal **210**) of the mounting structure **475** performs calibration motions through the gimbal controller **420** to automatically calibrate the gimbal compass **425** using the built-in motors of the gimbal **210**. Once the gimbal compass **425** is calibrated, data derived during this calibration may be transferred to the aerial vehicle **110**. The aerial vehicle **110** may add to the calibrated value the factory-calculated difference value so that the UAV compass **337** is now properly calibrated for flight. It is noted that in some embodiments, the factory-calculated difference value may be replaced by a user processed difference value. For example, a user may perform the initial or default calibration for use as the difference value.

[0054] FIG. **4**B illustrates a flow diagram for an example automatic compass calibration method **450**. The method **450** may start **455** with the gimbal **210** rotating **470** to an angular rotation. The gimbal **210** rotating **470** may include one or more commands being transmitted from the aerial vehicle **110** to the gimbal controller **420** through the gimbal interface **330**. The gimbal compass **425** measures **475** (e.g., with one or more magnetometers of the gimbal compass **425**) a magnetic field (e.g., the magnetic field of the earth) at the angular rotation. The measurement of the magnetic field may be stored in a memory of the gimbal **210** and/or the aerial vehicle **110** in association with the corresponding angular rotation.

[0055] After taking a magnetic field measurement, a loop condition may be checked **480**. If the loop condition is first condition (i.e., condition A), then the loop may enter a next iteration. That is, if the loop condition is condition A, the gimbal **210** may rotate **470** to a new angular rotation and the gimbal compass **425** may measure **475** the magnetic field at this new angular rotation. Alternately, if the loop condition is condition B (i.e., a condition mutually exclusive with condition A), a next sequence of steps may be performed. In this way, the method **455** may take a plurality of measurements of a magnetic field before proceeding to the next sequence of steps. Each measurement of the magnetic field may correspond to a respective angular rotation of a plurality of angular rotations. Each angular rotation may be unique, though this need not be the case in every embodiment. Each angular rotation may correspond to a rotation of the three motors of the gimbal **210**.

[0056] The loop condition check **480** may correspond to checking **480** a value of an iterated integer. That is, the method **450** may perform a predetermined number of iterations before moving on to the next step. In some embodiments, the loop condition may be based on a derived quality metric of the magnetic field measurements. For example, if the variation of measurements from a regression model is large the method **450** may perform more measurements (i.e., obtain a larger number of measurements) and conversely, if the measurements from the regression model is small the method **450** may perform fewer iterations (i.e., obtain fewer measurements). This regression model may be updated with each new measurement of the magnetic field. In some embodiments, the number of iterations may be based on the measured strength of the magnetic field. In some embodiments, the loop condition check **480** may be conditioned on an estimated probability that a calibration value should be within some range. In some embodiments, the loop condition check **480** may be conditioned on an estimated mean error and/or an estimated mean square error of an estimated calibration value.

[0057] After the measurements of the magnetic field have been obtained with the gimbal compass **425** (i.e., after the loop condition check **480** determines condition B), a calibration value for the gimbal compass **425** may be calculated **485**. This calibration value or data derived therefrom may be transferred **490** (e.g., via the gimbal interface **330**) to the aerial vehicle **110**. The aerial vehicle **110** may add **495** a calibration difference value to the calibration value to obtain a current calibration value for the aerial vehicle **110**. This current calibration value may be stored in a memory of the aerial vehicle **110**. After this, the aerial vehicle **110** may be ready **465** for a next action (e.g., ready to lift off for flight). Subsequently, the aerial vehicle **110** may determine its orientation (e.g., relative to one or more cardinal directions) based on a measurement with the UAV compass **337** of the aerial vehicle **110** and based on the current calibration.

[0058] In some embodiments, the calibration difference value may be a factory-calculated calibration value. That is, the calibration difference value may be empirically derived for the aerial vehicle **110** via a calibration process performed prior to the aerial vehicle **110** being retailed. In some embodiments, the calibration difference value is a predetermined value. In some embodiments, the calibration difference value is a user-defined calibration value. That is, the calibration difference value may be input by a user into the remote controller **120** or uploaded from another device to the aerial vehicle **110**.

[0059] In some embodiments, when the aerial vehicle **110** is ready **465**, it transmits a signal to the remote controller **120** indicating completion of the automatic calibration. The remote controller **120** may display an indication that the automatic calibration has completed successfully and/or stop displaying an indication that the UAV compass **337** is being calibrated. In some embodiments, the aerial vehicle illuminates one or more LEDs (e.g., LEDs **410**) as an indication of the completion of the automatic calibration. The LEDs may be on the aerial vehicle **110** and/or some other device (e.g., the remote controller **120**). It some embodiments, the aerial vehicle **110** and/or the remote controller **120** emits audio (e.g., via a speaker) when the aerial vehicle **110** is ready **465**.

Example Camera Architecture

[0060] FIG. **5** illustrates a block diagram of an example camera architecture. The camera architecture **505** corresponds to an architecture for the camera, e.g., **230**. Briefly referring back to the camera **230**, it may include a camera body, one or more a camera lenses, various indicators on the camera body (such as LEDs and/or displays), various input

mechanisms (such as buttons, switches, and touch-screen mechanisms), and electronics (e.g., imaging electronics, power electronics, and/or metadata sensors) internal to the camera body for capturing images via the one or more lenses and/or performing other functions. In one example embodiment, the camera **230** may be capable of capturing spherical or substantially spherical content. As used herein, spherical content may include still images or video having spherical or substantially spherical field of view. For example, in one embodiment, the camera **230** may capture video having a 360 degree field of view in the horizontal plane and a 180 degree field of view in the vertical plane. Alternatively, the camera **230** may capture substantially spherical images or video having less than 360 degrees in the horizontal direction and less than 180 degrees in the vertical direction (e.g., within 10% of the field of view associated with fully spherical content). In other embodiments, the camera **230** may capture images or video having a non-spherical wide angle field of view.

[0061] As described in greater detail below, the camera **230** may include sensors **540** to capture metadata associated with video data, such as timing data, motion data, speed data, acceleration data, altitude data and/or GPS data. In a particular embodiment, location and/or time centric metadata (e.g., geographic location, time, and/or speed) can be incorporated into a media file together with the captured content in order to track the location of the camera **230** over time. This metadata may be captured by the camera **230** itself or by another device (e.g., a mobile phone and/or the aerial vehicle **110** via the camera interface connectors **430**) proximate to the camera **230**. In one embodiment, the metadata may be incorporated with the content stream by the camera **230** as the spherical content is being captured. In another embodiment, a metadata file separate from the video file may be captured (by the same capture device or a different capture device) and the two separate files may be combined or otherwise processed together in post-processing. It is noted that these sensor **540** may be in addition to the sensors of the sensor subsystem **335**. In embodiments in which the camera **230** is integrated with the aerial vehicle **110**, the camera **230** may not have separate individual sensors **540**, but may rather rely upon the sensor subsystem **335** integrated with the aerial vehicle **110** and/or sensors of the gimbal **210**.

[0062] Referring now to the details of FIG. **5**, it illustrates a block diagram of the camera architecture **505** of the camera **230**, according to one example embodiment. In the illustrated embodiment, the camera **230** includes a camera core **510** that includes a lens **512**, an image sensor **514**, and an image processor **516**. The camera **230** may include a system controller **520** (e.g., a microcontroller or microprocessor) that controls the operation and functionality of the camera **230**. The camera **230** also may include a system memory **530** that is configured to store executable computer instructions that, when executed by the system controller **520** and/or the image processors **516**, may perform the camera functionalities described herein. In some example embodiments, a camera **230** may include multiple camera cores **510** to capture fields of view in different directions which may then be stitched together to form a cohesive image. For example, in an embodiment of a spherical camera system, the camera **230** may include two camera cores **510** each having a hemispherical or hyper hemispherical lens that each captures a hemispherical or hyper hemispherical field of view which are stitched together in post-processing to form a spherical image.

[0063] The lens **512** may be, for example, a wide angle lens, hemispherical, and/or hyper hemispherical lens that focuses light entering the lens to the image sensor **514** which captures images and/or video frames. The image sensor **514** may capture high-definition images having a resolution of, for example, 720p, 1080p, 4k, or higher. In one embodiment, spherical video is captured as 5760 pixels by 2880 pixels frames with a 360 degree horizontal field of view and a 180 degree vertical field of view. For video, the image sensor **514** may capture video at frame rates of, for example, 30 frames per second, 60 frames per second, or higher. The image processor **516** may perform one or more image processing functions of the captured images or video. For example, the image processor **516** may perform a Bayer transformation, demosaicing, noise reduction, image sharpening, image stabilization, rolling shutter artifact reduction, color space conversion, compression, and/or other in-camera processing functions. Processed images and/or video may be temporarily or persistently stored to the system memory **530** and/or to another non-volatile storage, which may be in the form of internal storage or an external memory card.

[0064] An input/output (I/O) interface **560** may transmit and/or receive data from various external devices. For example, the I/O interface **560** may facilitate the receiving or transmitting video or audio information through one or more I/O ports. Examples of I/O ports or interfaces include USB ports, HDMI ports, Ethernet ports, and audio ports. Furthermore, embodiments of the I/O interface **560** may include one or more wireless ports that may accommodate wireless connections. Examples of wireless ports include Bluetooth, Wireless USB, and/or Near Field Communication (NFC). The I/O interface **560** also may include an interface to synchronize the camera **230** with other cameras or with other external devices, such as a remote control, a second camera, a smartphone, a client device, and/or a video server.

[0065] A control/display subsystem **570** may include various control and display components associated with operation of the camera **230** including, for example, LED lights, a display, buttons, microphones, and/or speakers. The audio subsystem **550** may include, for example, one or more microphones and/or one or more audio processors to capture and process audio data correlated with video capture. In one embodiment, the audio subsystem **550** may include a microphone array having two or microphones arranged to obtain directional audio signals.

[0066] The sensors **540** may capture various metadata concurrently with, or separately from, video capture. For example, the sensors **540** may capture time-stamped location information based on a global positioning system (GPS) sensor, and/or an altimeter. Other sensors **540** may be used to detect and capture the orientation of the camera **230** including, for example, an orientation sensor, an accelerometer, a gyroscope, or a compass (e.g., a magnetometer compass). Sensor data captured from the various sensors **540** may be processed to generate other types of metadata. For example, sensor data from the accelerometer may be used to generate motion metadata that may include velocity and/or acceleration vectors representative of motion of the camera **230**.

[0067] Furthermore, sensor data from the aerial vehicle **110** and/or the gimbal **210** may be used to generate orien-

tation metadata describing the orientation of the camera **230**. Sensor data from a GPS sensor may provide GPS coordinates identifying the location of the camera **230**, and an altimeter may measures the altitude of the camera **230**. In one embodiment, the sensors **540** may be rigidly coupled to the camera **230** such that any motion, orientation or change in location experienced by the camera **230** is also experienced by the sensors **540**. The sensors **540** furthermore may associates a time stamp representing when the data was captured by each sensor. In one embodiment, the sensors **540** automatically begin collecting sensor metadata when the camera **230** begins recording a video.

Example Remote Control System

[0068] FIG. **6** illustrates a block diagram of an example remote control system **605** of a remote controller, e.g., remote controller **120**. The remote control system **605** may include a processing subsystem **610**, a navigation subsystem **620**, an input/output (I/O) subsystem **630**, a display subsystem **640**, an audio/visual (A/V) subsystem **650**, a control subsystem **660**, a communication subsystem **670**, and/or a power subsystem **680**. The subsystems may be communicatively coupled through a data bus **690** and may be powered, where necessary, through the power subsystem **680**.

[0069] The processing subsystem **610** may be configured to provide the electronic processing infrastructure to execute firmware and/or software comprised of instructions. An example processing subsystem **610** is illustrated and further described in FIG. **14**. The navigation subsystem **620** may include electronics, controls, and/or interfaces for navigation instrumentation for the remote controller **120**. The navigation subsystem **620** may include, for example, a global position system (GPS) and a compass (e.g., a compass including a magnetometer). The GPS and compass may be used to track the location of the remote controller **120**, which can be used to determine the position of the remote controller **120** relative to that of the aerial vehicle **110**, and vice versa.

[0070] The I/O subsystem **630** may include the input and output interfaces and electronic couplings to interface with devices that allow for transfer of information into or out of the remote controller **120**. For example, the I/O subsystem **630** may include a physical interface such as a universal serial bus (USB) or a media card (e.g., secure digital (SD)) slot. The I/O subsystem **630** also may be associated with the communication subsystems **670** to include a wireless interface such as Bluetooth. It is noted that in one example embodiment, the aerial vehicle **110** may use long-range Wi-Fi radio (or some other type of WLAN) via the communication subsystem **670**, but also may use a second Wi-Fi radio or cellular data radio (as a part of the I/O subsystem **630**) for connection to other wireless data enabled devices, for example, smart phones, tablets, laptop or desktop computers, and/or wireless internet access points. Moreover, the I/O subsystem **630** also may include other wireless interfaces, e.g., Bluetooth, for communicatively coupling to devices that are similarly wirelessly enabled for short-range communications.

[0071] The display subsystem **640** may be configured to provide an interface, electronics, and/or display drivers for the screen **170** of the remote controller **120**. The Audio/Visual (A/V) subsystem **650** may include interfaces, electronics, and/or drivers for an audio output (e.g., headphone jack or speakers) as well as visual indicators (e.g., LED lighting associated with, for example, the buttons **160** and/or button **165**).

[0072] The control subsystem **660** may include electronic and control logic and/or firmware for operation with the control panels **150**, **155**, buttons **160**, **165**, and other control mechanisms on the remote controller **120**.

[0073] The communication subsystem **670** may include electronics, firmware and/or interfaces for communications. The communications subsystem **670** may include one or more of wireless communication mechanisms such as Wi-Fi (short and long-range), long term evolution (LTE), 3G, 4G, and/or 5G. The communication subsystem **670** also may include wired communication mechanisms such as Ethernet, USB, and/or HDMI.

[0074] The power subsystem **680** may include electronics, firmware, and/or interfaces for providing power to the remote controller **120**. The power subsystem **680** may include direct current (DC) power sources (e.g., batteries), but also may be configured for alternating current (AC) power sources. The power subsystem **680** also may include power management processes for extending DC power source lifespan. It is noted that in some embodiments, the power subsystem **680** may include a power management integrated circuit and a low power microprocessor for power regulation. The microprocessor in such embodiments may be configured to provide very low power states to preserve battery, and may be able to wake from low power states from such events as a button press or an on-board sensor (like a hall sensor) trigger.

Example Flight Plan Control System for Remote Controller

[0075] Turning now to preparing an aerial vehicle, e.g., aerial vehicle **110**, for flight, the disclosed configuration may include mechanisms for programming the aerial vehicle **110** for flight through a remote controller, e.g., remote controller **120**. The example, a flight plan may be uploaded to the aerial vehicle **110**. In some embodiments, while the flight plan is being uploaded, the UAV compass **337** may be calibrated (e.g., via method **450**). The flight plan may provide the aerial vehicle **110** with basic flight related parameters, while the remote controller **120** is used to provide overall control of the aerial vehicle **110**.

[0076] FIG. **7** illustrates a functional block diagram of an example flight plan control system **705** for a remote controller (e.g., remote controller **120**). The system **705** may include a planning module **710**, a route plan database **720**, a route check module **730**, an avoidance database **740**, a system check module **750**, and/or a return factors database **760**. It is noted that the modules may be embodied as software (including firmware). The software may be program code (or software instructions) executable by the processing subsystem **610**.

[0077] The flight plan control system **705** may be configured to provide flight (or route) planning tools that allow for preparing a flight plan of the aerial vehicle **110**. The planning module **710** may include user interfaces displayed on the screen **170** of the remote controller **120** that allows for entering and viewing of information such as route (how and where the aerial vehicle **110** will travel), maps (geographic information over where the aerial vehicle **110** will travel), environmental condition data (e.g., wind speed and direction), terrain condition data (e.g., locations of tall dense

shrubs), and/or other information necessary for planning a flight of the aerial vehicle **110**.

[0078] The route plan database **720** may provide a repository (e.g., part of a storage device such as an example storage unit described with FIG. **14**) for prepared flight plans to be stored. The route plan database **720** may also store plans that were previously created on the remote controller **120** and/or uploaded into it (e.g., through the I/O subsystem **630**). The stored plans may be retrieved from the route plan database **720** and edited as appropriate through the planning module **710**.

[0079] The route plan database **720** also may store pre-planned (pre-programmed) maneuvers for the aerial vehicle **110** that may be retrieved and applied with a flight plan created through the planning module **710**. For example, a "loop de loop" maneuver may be pre-stored and retrieved from the route plan database **720** and then applied to a flight plan over a mapped area via the planning module **710**. The map of the mapped area may also be stored in and retrieved from the route plan database **720**. It is noted that the route plan may be configured to provide a predefined "band" (area or region where operation is permissible) within with the aerial vehicle **110** is controlled through the remote controller **120**.

[0080] The route check module **730** may be configured to conduct a check of the desired route to evaluate potential issues with the route planned. For example, the route check module **730** may be configured to identify particular factors such as terrain elevation that may be challenging for the aerial vehicle **110** to clear. The route check module **730** may check environment conditions along the planned route to provide information on potential challenges such as wind speed or direction.

[0081] The route check module **730** may also retrieve data from the avoidance database **740** for use in checking a particular planned route. The data stored in the avoidance database **740** may include data such as flight related restriction in terms of areas and/or boundaries for flight (e.g., no fly areas or no fly beyond a particular boundary (aerial restrictions)), altitude restrictions (e.g., no fly above a ceiling of some predefined altitude or height), proximity restrictions (e.g., power lines, vehicular traffic conditions, or crowds), and/or obstacle locations (e.g., monuments and/or trees). The data retrieved from the avoidance database **740** may be used to compare against data collected from the sensors on the aerial vehicle **110** to see whether the collected data corresponds with, for example, a predefined condition and/or whether the collected data is within a predetermined range of parameters that is within an acceptable range of error.

[0082] The route check module **730** also may include information corresponding to where the aerial vehicle **110** can or cannot set down. For example, the route check module **730** may incorporate information regarding where the aerial vehicle **110** cannot land ("no land zone"), such as, highways, bodies of water (e.g., a pond, stream, rivers, lakes, or ocean), and/or restricted areas. Some retrieved restrictions may be used to adjust the planned route before flight so that when the plan is uploaded into the aerial vehicle **110** a user is prevented from flying along a particular path or in a certain area (e.g., commands input by the user into the remote controller **120** are overridden by the remote controller **120** or the aerial vehicle **110**). Other retrieved restriction data from the avoidance database **740** may be stored with the route plan and also may be uploaded into the aerial vehicle **110** for use during the flight by the aerial vehicle **110**. The stored restriction data may be used to make route adjustments when detected, e.g., via the system check module **750** described below.

[0083] Referring back to the route check module **730**, it also may be configured to alter or provide recommendations to alter the route plan to remove conditions in the flight plan path that may not be conducive for the aerial vehicle **110** to fly through. The altered path or suggested path may be displayed through the planning module **710** on the screen **170** of the remote controller **120**. The revised route may be further modified if so desired and checked again by the route check module **730** in an iterative process until the route is shown as clear for flight of the aerial vehicle **110**.

[0084] The system check module **750** may be configured to communicate with the aerial vehicle **110**, e.g., through the communication subsystem **670**. The system check module **750** may receive data from the aerial vehicle **110** corresponding to conditions of the aerial vehicle **110** or the surroundings within which the aerial vehicle **110** is operating. The system check module **750** may interface with the planning module **710** and route check module **730** to make route adjustments for the aerial vehicle **110** as it operates and moves along the planned route.

[0085] The planning module **710**, and in some embodiments the route check module **730**, also may interface with the return factors database **760**. The return factors database **760** may store return related data corresponding to when the aerial vehicle **110** should return to a predefined spot. This data may be stored with the route plan and uploaded into the aerial vehicle **110**. The data also may be used by the system check module **750** to trigger an action for the aerial vehicle **110** to fly to the return location. The return data may be data related to the aerial vehicle **110**, such as battery power (e.g., return if battery power is below a predefined threshold that would prevent return of the aerial vehicle **110**) or a mechanical condition (e.g., rotor engine stall, burnout, and/or another malfunction). The return data also may be environment data (e.g., wind speed in excess of a predefined threshold) and/or terrain data (e.g., tree density beyond predefined threshold). The return location may be predefined through the planning module **710** by providing, for example, GPS coordinates. Alternately, it may be the location of the remote controller **120**. The aerial vehicle **110** may be configured to set down at or near its current location if the system check module **750** determines that the aerial vehicle **110** will not be able to return to the predefined location in view of the return data information received.

[0086] It is noted that the databases **720**, **740**, **760** of the system **705** may be updated and/or augmented. For example, where there may be a local WLAN (e.g., Wi-Fi) or cellular data connection, e.g., through the I/O subsystem **630**, the data gathered from sources such as the internet may be used to update the route plan database **720**, the avoidance database **740**, and the return factors database **760**. Moreover, with such data communication, the databases may be updated in real-time so that information may be updated and utilized during flight. Further, the updated data may be transmitted to the communication subsystem **360** of the aerial vehicle **110** in real-time to update the route plan or return path information (further described below) as it becomes available.

[0087] Additional examples of route plan related configurations on a remote controller **120** are described with FIGS. **9** and **10**. FIG. **9** illustrates a flow diagram for an example route plan programmed on a remote controller **120**. The process may start **910** with the remote control system **605** determining **915** whether there is pre-defined flight route (or path). If not, the process may receive flight route details **920** using, for example, the planning module **710** and route planning database **720**. The process analyzes **925** route restrictions using, for example, the route check module **730** and avoidance database **740**. The process also may analyzes **930** system constraints through, for example, the avoidance database and system check module **750** (e.g., battery life left on aerial vehicle **110**). The process may upload **935** the route details to the aerial vehicle **110**. The route also may be stored in the route plan database **720** before being ready for the next actions **945**.

[0088] If the process determines **915** that a predefined route will be used, that route plan may be retrieved from the route plan database **720**. The retrieved route plan may be uploaded **935** to the aerial vehicle **935**. If adjustments are made to the retrieved route plan, the process may undertake the steps of analyzing **925** the route restrictions and analyzing **930** the system constraints before being uploaded **935** to the aerial vehicle **110**. The processes of analyzing **925**, **930** may be iterative before upload **935** and before being ready **945** for the next actions.

[0089] Turning to FIG. **10**, it illustrates a flow diagram for an example program load operation onto the aerial vehicle **110**. The process may start **1010** with the flight controller **315** processing subsystem receiving **1015** the route information from the remote controller **120**. The received route information may be stored **1020** in a storage (e.g., memory and/or flash storage). When ready for execution, the process may retrieve the stored route information and load **1025** the route information and/or corresponding executable code for execution by the flight controller **315** processing subsystem. Subsequent to this, the aerial vehicle **110** may be ready **1030** for flight using the loaded route information.

Example Flight Control System for Aerial Vehicle

[0090] Turning now to FIG. **8**, it illustrates a functional block diagram of an example flight control system **805** for a remote controlled aerial vehicle, e.g., aerial vehicle **110**. The flight control system **805** may include a route plan module **810**, a systems check module **820**, a control module **830**, tracking module **840**, a local route database **850**, and/or a tracking database **860**.

[0091] It is noted that the modules of the flight control system **805** may be embodied as software (including firmware). The software may be program code (or software instructions) stored in a storage medium and executable by the flight controller **315** processing subsystem.

[0092] The route plan module **810** may be configured to execute the route plan for the aerial vehicle **110**. The route plan may be one uploaded from the remote controller **120** as described in conjunction with FIG. **10**. The route plan may be transmitted via the communication subsystem **670** of the remote controller **120** and received by the communication subsystem **360** of the aerial vehicle **110**. The route plan may be configured to provide a predefined "band" within which the aerial vehicle **110** is controlled. The systems check module **820** may be configured to monitor operational systems of the aerial vehicle **110** and flight environment and terrain sensor data captured by the aerial vehicle **110** when in operation. The operational systems information may include information related to flight of the aerial vehicle **110**, for example, remaining battery power, mechanical operation, and/or electrical operation. Flight environment and terrain sensor data may correspond to data from the sensor subsystem **335** of the aerial vehicle **110**, for example, temperature, moisture, wind direction, object detection, altitude, and/or direction (e.g., heading) data.

[0093] The control module **830** may be configured to control operation of the aerial vehicle **110** when it is in flight. The control module **830** may be configured to receive control commands from the remote controller **120**. The received commands may be, for example, generated via the control panels **150**, **155** and transmitted from the communication subsystem **670** of the remote controller **120** for receiving and processing at the aerial vehicle **110** via its communication subsystem **360** and flight controller **315**. The received commands may be used by the control module **830** to manipulate the appropriate electrical and mechanical subsystems of the aerial vehicle **110** to carry out the control desired.

[0094] The control module **830** also may interface with the route plan module **810** and the systems check module **820** to ensure that the controls executed are within the permissible parameter of the route (or path) provided by the route plan module **810**. Further, when an aerial vehicle **110** is in flight, there may be instances in which early detection of potential problems may be beneficial so that course (including flight) modifications can be taken when necessary and feasible. The control module **830** also may make course changes in view of receiving information from the systems check module **820** that may indicate that such course correction is necessary, for example, to navigate around an object detected by the sensor subsystem **335** and/or detected and analyzed by the camera **230**. Other example course changes may occur due to wind levels exceeding a threshold at a particular altitude so that the aerial vehicle **110** may move to a lower altitude where wind may be less of an issue despite the control information received from the remote controller **120**. In making these changes, the control module **830** may work with the tracking module **860** to update the local route database **850** to identify locations of objects or identify areas of flight that would be identified for avoidance for other reasons (e.g., weather conditions and/or electronic interference) for tracking by the tracking module **840** and for later upload to an avoidance database, e.g., avoidance database **740**.

[0095] The tracking module **840** may be configured to track the flight of the aerial vehicle **110** (e.g., data corresponding to "clear" path of flying). The tracking module **840** also may store this information in the track database **860** and/or may store information in the local route database **850**. The tracking module **840** may be used to retrieve the route the aerial vehicle **110** actually took and use that data to track back to a particular location (e.g., the return location). This may be of particularly interest in situations in which the aerial vehicle **110** needs to be set down (e.g., land) as quickly as possible and/or execute a return path. For example, if the systems check module **820** detects an impending power, electrical, and/or mechanical issue that may affect further flying of the aerial vehicle **110**, it may instruct the control module **830** to configure itself into an override mode. In the override mode, the control module **830** may limit or cut off

the control information received from the remote controller **120**. The control module **830** may retrieve a return path from the tracking module **840** for the aerial vehicle **110** to identify a location where the aerial vehicle **110** can be set down as quickly as possible based on data from the systems control module **820**, e.g., amount of battery power remaining and/or execute a return path. For example, upon executing a return path, the control module **830** may determine that the battery power left does not allow for return to a predefined location and determine that the aerial vehicle **110** may instead need to land somewhere along the clear path.

[0096] FIG. **11** provides an example of additional details for flight control operation on the aerial vehicle **110**. In particular, FIG. **11** illustrates a flow diagram for an example program path operation on the remote controlled aerial vehicle **110**. The process may start **1110** with control information being received from the remote controller **120** through the communication subsystem **360** of the aerial vehicle **110**. The control information may be processed by the flight controller **315** to control **1115** the mechanical and electrical components of the aerial vehicle **110** within the context of the programmed flight route. The sensor subsystem **335** may receive **1120** flight data information from sensors on board the aerial vehicle **110**. This sensor data may include an orientation of the aerial vehicle **110** detected by the UAV compass **337**. This data may be analyzed **1125** by the systems check module **820**. The control module **830** may augment **1130** the analyzed data based on other information to modify the route, e.g., detection of an object by the sensor subsystem **335** and/or image analysis of an image captured by the camera **230**. In such instances, the aerial vehicle **110** flight route may be adjusted **1135** by the control module **830**. When the flight route is completed **1140**, the aerial vehicle **110** may continue to fly within the parameters of system operation and flight route (or path) until the aerial vehicle **110** has landed **1145**. It is noted that the aerial vehicle **110** may be configured not to land within locations predefined as "no land zones." In such situations, a user of the remote controller **120** may continue to fly the aerial vehicle **110** to an area where landing **1145** is permitted.

Example Return Path Operation on Aerial Vehicle

[0097] As noted previously, there may be instances in which the aerial vehicle **110** may need to execute a return path. For example, operational conditions on the aerial vehicle **110** or a signal of return to home from the remote controller **120** may trigger a return path. On the aerial vehicle **110**, the route plan module **810**, control module **830** and/or tracking module **840** may be configured to provide a return path. The return path may have been preprogrammed from the flight plan, but thereafter modified with information picked up during flight of the aerial vehicle **110** and stored during flight. For example, during flight, the sensors on the aerial vehicle **110** may detect obstacles that should be avoided that obstruct the pre-programmed return path. A detected obstacle and/or corresponding location data (e.g., GPS coordinates or points) of that obstacle may be stored in the local route database **850**. The route plan module **810**, control module **830**, and/or tracking module **840** may execute a return path operation on the aerial vehicle **110**. The return path operation may include retrieving the return path program, extracting data corresponding to obstacles (or other avoidance data) determined to be in the return path that were detected and stored during flight, revising the return path program to adjust for those obstacles (e.g., changes route to clear object), and/or executing the modified return path so that the obstacles are avoided on the return path.

[0098] The disclosed configuration may beneficially implement an intelligent return to home behavior for the aerial vehicle **110**. The return to home configuration may use a return path that is a direct path from a current location to a predefined location. Alternately, or in addition, the direct route may incorporate obstacle avoidance. By way of example, assume during flight the aerial vehicle **110** flies around a tree. This data (e.g., location data) may be stored in the aerial vehicle **110**. Later, if a "return to home" (or "come home") button is selected on the remote controller **120**, the aerial vehicle **110** return path may track back along the direct route while avoiding the tree, which is identified as an obstacle. Hence, the disclosed configuration return path may track back along what may be a clear path on the way back because such path avoided obstacles. In addition, the clear path may be direct path from a current location to a predetermined location (e.g., an initial take off location and/or initial location where data was captured) and may avoid redundant points along the route (e.g., multiple passes around a tree or building). The clear path may be saved within the aerial vehicle **110**. In addition, if the UAV compass **337** is automatically-calibrated prior to flight as previously described, the return path executed may be capable of automatic guidance along a path that should correspond to the expected directional path. In some example embodiments, in addition to obstacle avoidance, the return path program may use a direct route back to the predefined location to land or a place to land along that route that is determined to be clear. Landing at a place other than the predefined location may be due to other factors coming into consideration, for example, if battery power is insufficient to return to predefined location or mechanical integrity would prevent return to predefined location.

[0099] The disclosed configuration may reduce or remove aspects of flight behavior of the aerial vehicle **110** that would be unnecessary for a return path. For example if the aerial vehicle **110** flew several loops around a tree, it may be undesirable to backtrack all of the loops when on a return path. Accordingly, the aerial vehicle **110** may be configured to mark areas as "clear" (i.e., areas that are clear may then be identified through "clear breadcrumbs") as the aerial vehicle **110** is in flight. The clear path may be generated, for example, by removing location data (e.g., GPS) of the tracked flight path that may be redundant and/or accounting for obstacle data that may have been collected so as to avoid those obstacles. Further, it may be a direct flight path from a current location of the aerial vehicle to a predetermined location (e.g., initial take off location). The data corresponding to "clear" may be assembled into a graph for use in a return path. Thereafter, if the aerial vehicle **110** needs to come back (e.g., execute a return path) to the starting location, the aerial vehicle **110** may take the shortest path through the graph of the cleared areas. This information may be stored and used through the control module **830** and/or the tracking module **840**. Hence, if the aerial vehicle **110** flew a path with several loops and figure eights and this path self-intersects, the control module **840** may make connections at those intersections, build a graph corresponding to the intersections in that flight, and take a shortest path through cleared area back to a return location, for example, by removing redundant location data collected along the

flight path. The process also may use an initial take off location of the aerial vehicle **110** (e.g., where the aerial vehicle **100** started flying from) as the return location.

[0100] FIG. **12** illustrates a flow diagram for an example return path operation on a remote controlled aerial vehicle **110**. The return path may be executed due to voluntary action, e.g., user selection of the return button **165** on the remote controller **120**, or through involuntary action. Involuntary actions may include system related issue on the aerial vehicle **110**, for example, low battery power, mechanical issues, and/or electrical issues. The involuntary actions may also be triggered by sources such as location information or environmental information such as flying in a defined boundary or area, weather and climatic issues (e.g., wind and/or precipitation), and/or physical considerations such as object density (e.g., the density of trees in a geographic area). The aerial vehicle **110** monitoring may be set up through the return factors database **760** and monitored for triggering of a return condition through the system check module **820**, which may work in conjunction with the control module **830** to trigger a return mode.

[0101] In this example, the return path operation may start **1210** by detection **1215** of a return condition, for example, the systems check module **820** detecting an impending power, electrical, and/or mechanical issue. The control module **830**, in conjunction with the route plan module **810** may trigger a reprogramming **1220** of the aerial vehicle **110** to now follow a return path. The control module **830** may work in conjunction with the route plan module **810**, which may have preprogrammed coordinates of a return location. Also, the control module **830** may work in conjunction with the tracking module **840**, which may include information on possible return paths accounting for potential obstacles as may have been logged in the track database **860** during flight of the aerial vehicle **110**. It is noted that, in some embodiments, the aerial vehicle **110** also may track "clear" areas during flight and store those locations. Thereafter, if a return path is triggered, either manually or automatically, the "cleared" location data points may be retrieved to generate a return flight path that the control module **830** can execute. This configuration may be beneficial, for example, if no return path is programmed or circumstances do not allow for return to a precise return location (e.g., a "home" location).

[0102] As the return flight path is executed and the aerial vehicle **110** enters the return mode, the control module **830** may override control information arriving from the remote controller **120** and engage in an auto-pilot to navigate to the location pre-defined with the return to home. If there are flight adjustments **1225**, the process may alter the return flight path according to information stored and processed by the tracking module **840**, the track database **860**, and/or the local route database **850**. The control module **830** may be configured to control **1240** the aerial vehicle **110** back to the return location **1250**. The return location **1250** may be identified in the route plan module **810** (e.g., the original route plan may include coordinates for a return location), may use the location of the remote controller **120** (e.g., using its GPS location) as a return location, and/or may identify an intermediate location as determined through the local route database **850** and/or the track database **860** in conjunction with the tracking module **840** and the route plan module **810**.

[0103] It is noted that other operational scenarios also may trigger a return flight path. For example, the systems check module **820** may closely monitor maintenance of a communication link (e.g., wireless link **125**) between the communications subsystem **360** of the aerial vehicle **110** and the communication subsystem **670** of the remote controller **120**. A loss of a communication link between the communications subsystem **360** of the aerial vehicle **110** and the communication subsystem **670** of the remote controller **120** may trigger a return path. In this example, the system may be configured so that if the communication link has been severed, the systems check module **820** notifies the control module **830** to try to reestablish the communication link. If the communication link is not established within a predefined number of tries or a predefined time period, the control module **830** may trigger the start of the return flight path as described above.

Remote Controller User Interface Example

[0104] FIG. **13** illustrates an example user interface **1305** for use with the remote controller **120**. The user interface **1305** may be configured for display on the screen **170** of the remote controller **120**. In this example, the user interface **1305** corresponds to a "dashboard" for the aerial vehicle **110**. In one embodiment, the remote controller **120** may receive, e.g., via the I/O subsystem **630** and/or communications subsystem **670**, sensor data logged by the sensor subsystem **335** (and transmitted via the communication subsystem **360**) of the aerial vehicle **110** as it is in flight. In one example embodiment, the aerial vehicle **110** may incorporate the telemetric (or sensor) data with video that is transmitted back to the remote controller **120** in real time. The received telemetric data may be extracted from the video data stream and incorporate into predefine templates for display with the video on the screen **170** of the remote controller **120**. The telemetric data also may be transmitted separate from the video from the aerial vehicle **110** to the remote controller **120**. Synchronization methods such as time and/or location information may be used to synchronize the telemetric data with the video at the remote controller **120**. This example configuration may allow a user, e.g., operator, of the remote controller **120** to see where the aerial vehicle **110** is flying along with corresponding telemetric data associated with the aerial vehicle **110** at that point in the flight. Further, if the user is not interested in telemetric data being displayed real-time, the data may still be received and later applied for playback with the templates applied to the video.

[0105] The predefine templates may correspond to "gauges" that provide a visual representation of speed, altitude, and charts, e.g., as a speedometer, altitude chart, and a terrain map. The populated templates, which may appear as gauges on screen **170** of the remote controller **120**, may further be shared, e.g., via social media, and/or saved for later retrieval and use. For example, a user may share a gauge with another user by selecting a gauge (or a set of gauges) for export. Export may be initiated by clicking the appropriate export button, or a drag and drop of the gauge(s). A file with a predefined extension may be created at the desired location. The gauge may be selected and be structured with a runtime version of the gauge or may be played back through software that can read the file extension.

Example Machine Architecture

[0106] As has been noted, the remote controlled aerial vehicle **110** may be remotely controlled by the remote

controller **120**. The aerial vehicle **110** and the remote controller **120** may be machines that may be configured to operate using software. FIG. **13** is a block diagram illustrating components of an example machine able to read instructions from a machine-readable medium and execute them in one or more processors (or controllers). All or portions of the example machine described in FIG. **14** may be used with the aerial vehicle **110** and/or the remote controller **120** and/or other parts of a system that interfaces with the aerial vehicle **110** and/or remote controller **120**.

[0107] In FIG. **14**, there is a diagrammatic representation of a machine in the example form of a computer system **1400**. The computer system **1400** may be used to execute instructions **1424** (e.g., program code or software) for causing the machine to perform any one or more of the methodologies (or processes) described herein. In some embodiments, the machine may operate as a standalone device or a connected (e.g., networked) device that connects to other machines. In a networked deployment, the machine may operate in the capacity of a server machine or a client machine in a server-client network environment, or as a peer machine in a peer-to-peer (or distributed) network environment.

[0108] The machine in this example may be a handheld controller (e.g., remote controller **120**) to control the remote controlled aerial vehicle **110**. The architecture described also may be applicable to other computer systems that operate in the system of the remote controlled aerial vehicle **110** with camera and mounting configuration, e.g., in setting up a local positioning system. These other example computer systems may include a server computer, a client computer, a personal computer (PC), a tablet PC, a smartphone, an internet of things (IoT) appliance, a network router, switch or bridge, and/or any machine capable of executing instructions **1424** (sequential or otherwise) that specify actions to be taken by that machine. Further, while only a single machine is illustrated, the term "machine" may also refer to include any collection of machines that individually or jointly execute instructions **1424** to perform any one or more of the methodologies discussed herein.

[0109] The example computer system **1400** includes one or more processing units (generally processor **1402**). The processor **1402** may be, for example, a central processing unit (CPU), a graphics processing unit (GPU), a digital signal processor (DSP), a controller, a state machine, one or more application specific integrated circuits (ASICs), one or more radio-frequency integrated circuits (RFICs), and/or any combination of these. The computer system **1400** also may include a main memory **1404**. The computer system **1400** may include a storage unit **1416**. The processor **102**, memory **1404** and/or the storage unit **1416** may communicate via a bus **1408**.

[0110] In addition, the computer system **1400** may include a static memory **1406**, a display driver **1410** (e.g., to drive a screen (e.g., screen **170**) such as a plasma display panel (PDP), a liquid crystal display (LCD), and/or a projector). The computer system **1400** may also include input/output devices, e.g., an alphanumeric input device **1412** (e.g., a keyboard), a dimensional (e.g., 2-D or 3-D) control device **1414** (e.g., a mouse, a trackball, a joystick, a motion sensor, and/or other pointing instrument), a signal generation device **1418** (e.g., a speaker), and/or a network interface device **1420**, which also may be configured to communicate via the bus **1408**.

[0111] The storage unit **1416** may include a machine-readable medium **1422** on which is stored instructions **1424** (e.g., software) embodying any one or more of the methodologies or functions described herein. The instructions **1424** also may reside, completely or at least partially, within the main memory **1404** or within the processor **1402** (e.g., within a processor's cache memory) during execution thereof by the computer system **1400**. The main memory **1404** and the processor **1402** also may constitute machine-readable media. The instructions **1424** may be transmitted or received over a network **1426** via the network interface device **1420**.

[0112] While the machine-readable medium **1422** is shown in the example embodiment depicted in FIG. **14** to be a single medium, the term "machine-readable medium" may refer to a single medium or multiple media (e.g., a centralized database, a distributed database, and/or associated caches and servers) able to store the instructions **1424**. The term "machine-readable medium" may also refer to any medium that is capable of storing instructions **1424** for execution by the machine and that cause the machine to perform any one or more of the methodologies disclosed herein. The term "machine-readable medium" may include, but is not limited to, data repositories in the form of solid-state memories, optical media, and magnetic media.

ADDITIONAL CONSIDERATIONS

[0113] The disclosed configuration may beneficially execute the detection of conditions in an aerial vehicle that automatically triggers a return path for having the aerial vehicle return and/or set down in a predefined location. Moreover, the disclosed configurations also may apply to other vehicles to automatically detect and trigger a return path.

[0114] Throughout this specification, plural instances may implement components, operations, or structures described as a single instance. Although individual operations of one or more methods may be illustrated and described as separate operations, one or more of the individual operations may be performed concurrently. The operations may not be required to be performed in the order illustrated. Structures and functionality presented as separate components in example configurations may be implemented as a combined structure or component. Similarly, structures and functionality presented as a single component may be implemented as separate components. These and other variations, modifications, additions, and improvements may fall within the scope of the subject matter herein.

[0115] Certain embodiments are described herein as including logic or a number of components, modules, or mechanisms, for example, as illustrated in FIGS. **3-12**. Modules may constitute either software modules (e.g., code embodied on a machine-readable medium or in a transmission signal), hardware modules, or a combination of hardware and software. A hardware module may be a tangible unit capable of performing certain operations and may be configured or arranged in a certain manner. In example embodiments, one or more computer systems (e.g., a standalone, client or server computer system) or one or more hardware modules of a computer system (e.g., a processor or a group of processors) may be configured by software (e.g., an application or application portion) as a hardware module that operates to perform certain operations as described herein.

[0116] In various embodiments, a hardware module may be implemented mechanically or electronically. For example, a hardware module may include dedicated circuitry or logic that is permanently configured (e.g., as a special-purpose processor, such as a field programmable gate array (FPGA) or an application-specific integrated circuit (ASIC)) to perform certain operations. A hardware module may also include programmable logic or circuitry (e.g., as encompassed within a general-purpose processor or other programmable processor) that is temporarily configured by software to perform certain operations. It will be appreciated that the decision to implement a hardware module mechanically, in dedicated and permanently configured circuitry, or in temporarily configured circuitry (e.g., configured by software) may be driven by cost and time considerations.

[0117] The various operations of example methods described herein may be performed, at least partially, by one or more processors, e.g., processor **1402**, that are temporarily configured (e.g., by software) or permanently configured to perform the relevant operations. Whether temporarily or permanently configured, such processors may constitute processor-implemented modules that operate to perform one or more operations or functions. The modules referred to herein may, in some example embodiments, include processor-implemented modules.

[0118] The one or more processors may also operate to support performance of the relevant operations in a "cloud computing" environment or as a "software as a service" (SaaS). For example, at least some of the operations may be performed by a group of computers (as examples of machines including processors), these operations being accessible via a network (e.g., the Internet) and via one or more appropriate interfaces (e.g., application program interfaces (APIs)).

[0119] The performance of some of the operations may be distributed among the one or more processors, not only residing within a single machine, but deployed across a number of machines. In some example embodiments, the one or more processors or processor-implemented modules may be located in a single geographic location (e.g., within a home environment, an office environment, or a server farm). In other example embodiments, the one or more processors or processor-implemented modules may be distributed across a number of geographic locations.

[0120] Some portions of this specification are presented in terms of algorithms or symbolic representations of operations on data stored as bits or binary digital signals within a machine memory (e.g., a computer memory). These algorithms or symbolic representations may be examples of techniques used by those of ordinary skill in the data processing arts to convey the substance of their work to others skilled in the art. As used herein, an "algorithm" may refer to self-consistent sequence of operations or similar processing leading to a desired result. In this context, algorithms and operations may involve physical manipulation of physical quantities. Typically, but not necessarily, such quantities may take the form of electrical, magnetic, or optical signals capable of being stored, accessed, transferred, combined, compared, or otherwise manipulated by a machine. It may be convenient at times, principally for reasons of common usage, to refer to such signals using words such as "data," "content," "bits," "values," "elements," "symbols," "characters," "terms," "numbers," and/or "numerals." These words, however, are merely convenient labels and are to be associated with appropriate physical quantities.

[0121] Unless specifically stated otherwise, discussions herein using words such as "processing," "computing," "calculating," "determining," "presenting," and/or "displaying" may refer to actions or processes of a machine (e.g., a computer) that manipulates or transforms data represented as physical (e.g., electronic, magnetic, or optical) quantities within one or more memories (e.g., volatile memory, non-volatile memory, or a combination thereof), registers, or other machine components that receive, store, transmit, or display information.

[0122] As used herein any reference to "one embodiment" or "an embodiment" means that a particular element, feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. The appearances of the phrase "in one embodiment" in various places in the specification are not necessarily all referring to the same embodiment.

[0123] Some embodiments may be described using the expression "coupled" and "connected" along with their derivatives. For example, some embodiments may be described using the term "coupled" to indicate that two or more elements are in direct physical or electrical contact. The term "coupled," however, may also mean that two or more elements are not in direct contact with each other, but yet still co-operate or interact with each other. The embodiments are not limited in this context.

[0124] As used herein, the terms "comprises," "comprising," "includes," "including," "has," "having" or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a process, method, article, and/or apparatus that comprises a list of elements may not necessarily limited to only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus. Further, unless expressly stated to the contrary, "or" may refer to an inclusive or rather than to an exclusive or. For example, a condition A or B may be satisfied by any one of the following: A is true (or present) and B is false (or not present), A is false (or not present) and B is true (or present), and both A and B are true (or present).

[0125] In addition, use of the "a" or "an" are employed to describe elements and components of the embodiments herein. This may be done merely for convenience and to give a general sense of the invention. This description should be read to include one or at least one and the singular also includes the plural unless it is obvious that it is meant otherwise.

[0126] Upon reading this disclosure, those of skill in the art may appreciate still additional alternative structural and functional designs for a system and a process for automatically detecting and executing a return path for a vehicle through the disclosed principles herein. Thus, while particular embodiments and applications have been illustrated and described, it is to be understood that the disclosed embodiments are not limited to the precise construction and components disclosed herein. Various modifications, changes and variations, which may be apparent to those skilled in the art, may be made in the arrangement, operation and details of the method and apparatus disclosed herein without departing from the spirit and scope defined in the appended claims.

What is claimed is:

1. A method to automatically calibrate a compass of an aerial vehicle, the method comprising:

rotating a gimbal coupled with the aerial vehicle to a plurality of angular rotations;

measuring a magnetic field, with a gimbal compass of the gimbal, at the plurality of angular rotations to obtain a plurality of measurements;

calculating a calibration value for the gimbal compass based on the measurements;

transferring the calibration value to the aerial vehicle;

adding a calibration difference value to the calibration value to obtain a current calibration value for the aerial vehicle; and

storing the current calibration for use with the compass of the aerial vehicle.

2. The method of claim **1**, wherein the calibration difference value is a factory-calculated calibration value.

3. The method of claim **1**, wherein the calibration difference value is a user-defined calibration value.

4. The method of claim **1**, wherein the aerial vehicle transmits a signal to a remote controller indicating completion of the automatic calibration.

5. The method of claim **1**, wherein the aerial vehicle illuminates an LED as an indication of completion of the automatic calibration.

6. The method of claim **1**, wherein the aerial vehicle determines its orientation based on a measurement with the compass of the aerial vehicle and based on the current calibration.

7. A method to automatically calibrate a compass of an aerial vehicle, the method comprising:

powering up an aerial vehicle;

rotating a gimbal coupled with the aerial vehicle in a wide range of angular rotations;

calibrating, in response to the rotations, a gimbal compass of the gimbal to obtain a calibration value, the gimbal compass including a magnetometer;

transferring the calibration value to the aerial vehicle;

adding a calibration difference value to the calibration value to obtain a current calibration value for the aerial vehicle; and

storing the current calibration for use with the compass of the aerial vehicle.

8. The method of claim **7**, wherein the calibration difference value is a factory-calculated calibration value.

9. The method of claim **7**, wherein the calibration difference value is a user-defined calibration value.

10. The method of claim **7**, wherein the aerial vehicle transmits a signal to a remote controller indicating completion of the automatic calibration.

11. The method of claim **7**, wherein the aerial vehicle illuminates an LED as an indication of completion of the automatic calibration.

12. The method of claim **7**, wherein the aerial vehicle determines its orientation based on a measurement with the compass of the aerial vehicle and based on the current calibration.

13. A computer readable storage medium comprising stored instructions to automatically calibrate a compass of an aerial vehicle, the instructions when executed by a processor cause the processor to:

power up an aerial vehicle;

rotate a gimbal coupled with the aerial vehicle in a wide range of angular rotations;

calibrate, in response to the rotations, a gimbal compass of the gimbal to obtain a calibration value, the gimbal compass including a magnetometer;

transfer the calibration value to the aerial vehicle;

add a calibration difference value to the calibration value to obtain a current calibration for the aerial vehicle; and

store the current calibration for use with the compass of the aerial vehicle.

12. The computer readable storage medium of claim **13**, wherein the calibration difference value is a factory-calculated calibration value.

13. The computer readable storage medium of claim **13**, wherein the calibration difference value is a user-defined calibration value.

14. The computer readable storage medium of claim **13**, further comprising stored instructions that when executed by the processor causes the processor to transmit a signal to a remote controller indicating completion of the automatic calibration.

15. The computer readable storage medium of claim **13**, further comprising stored instructions that when executed by the processor causes the processor to illuminate an LED as an indication of completion of the automatic calibration.

16. The method of claim **13**, wherein the aerial vehicle determines its orientation based on a measurement with the compass of the aerial vehicle and based on the current calibration.

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