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(54) METHOD AND SYSTEM FOR DIRECTING UNMANNED VEHICLES

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(21) Appl. No.: **12/555,925**

(22) Filed: **Sep. 9, 2009**

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Related U.S. Application Data

(60) Provisional application No. 61/191,426, filed on Sep. 9, 2008.

(51) **Int. Cl.**
G05D 1/00 (2006.01)

(52) **U.S. Cl.**
USPC **701/2**; 244/190

(58) **Field of Classification Search**
USPC 701/2; 244/190
See application file for complete search history.

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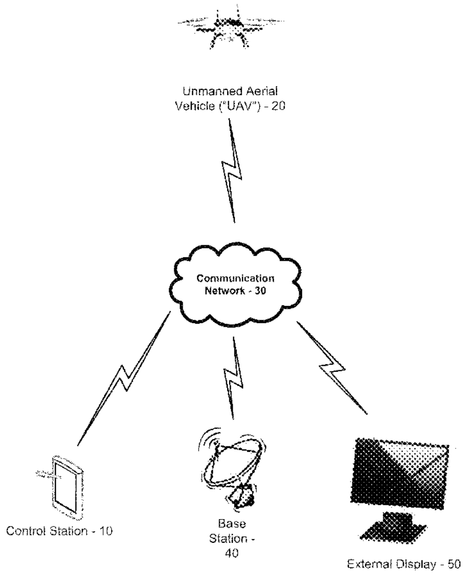
(57) ABSTRACT

A method of remotely controlling an aerial vehicle within an environment, including providing a control station in communication with the aerial vehicle, providing a map of the environment, receiving target world coordinates for the aerial vehicle within the environment, determining a desired velocity vector to direct the aerial vehicle to the target world coordinates at a speed proportional to the distance between the aerial vehicle and the target world coordinates, and directing the aerial vehicle along the desired velocity vector until the aerial vehicle reaches the target world coordinates.

26 Claims, 20 Drawing Sheets


Unmanned Aerial Vehicle ("UAV") - 20
Communication Network - 30
Control Station - 10
Base Station - 40
External Display - 50

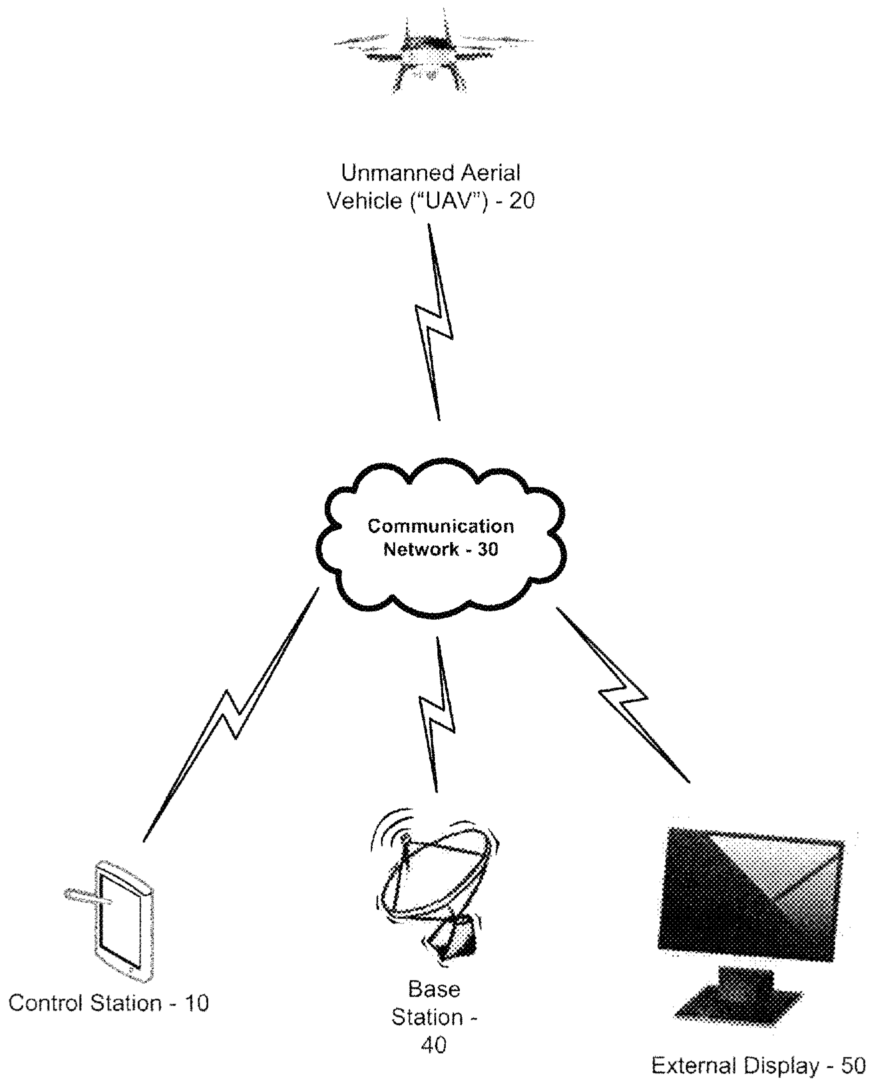
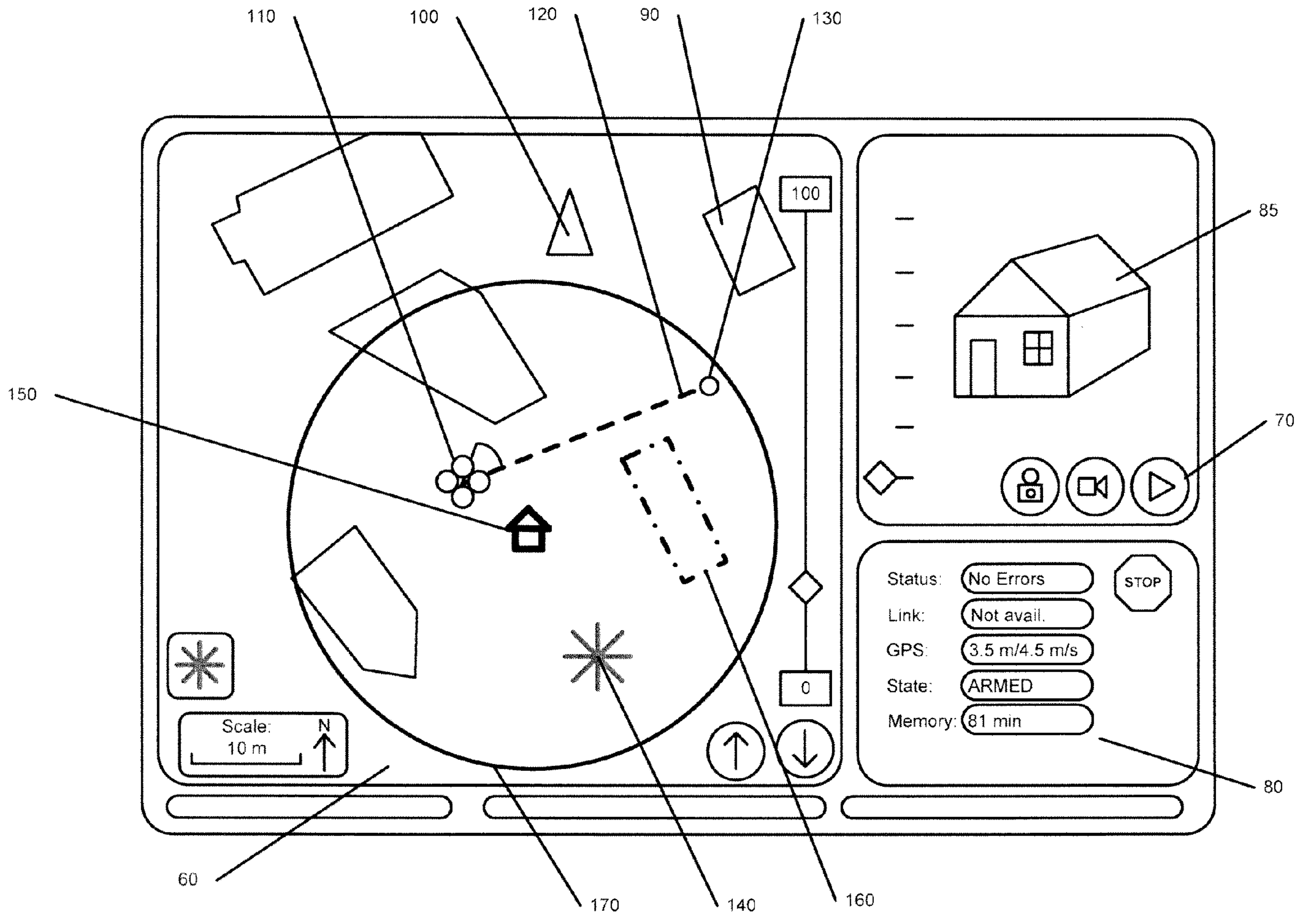

Unmanned Aerial Vehicle ("UAV") - 20
Communication Network - 30
Control Station - 10
Base Station - 40
External Display - 50

FIG. 1



Status: No Errors

Link: Not avail.

GPS: 3.5 m/4.5 m/s

State: ARMED

Memory: 81 min

FIG. 2

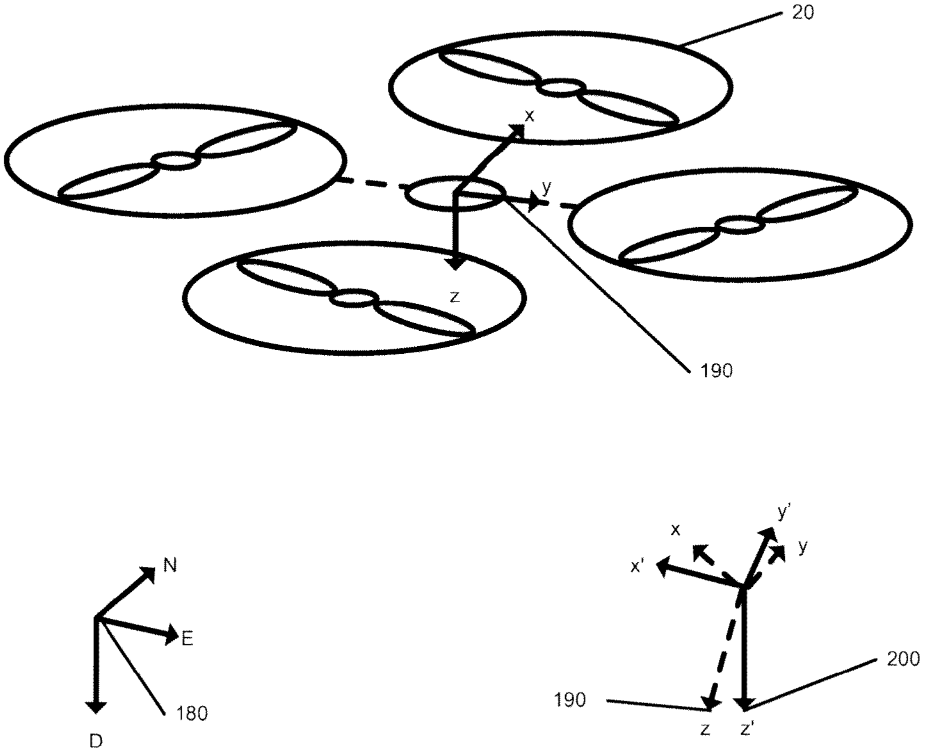


FIG. 3

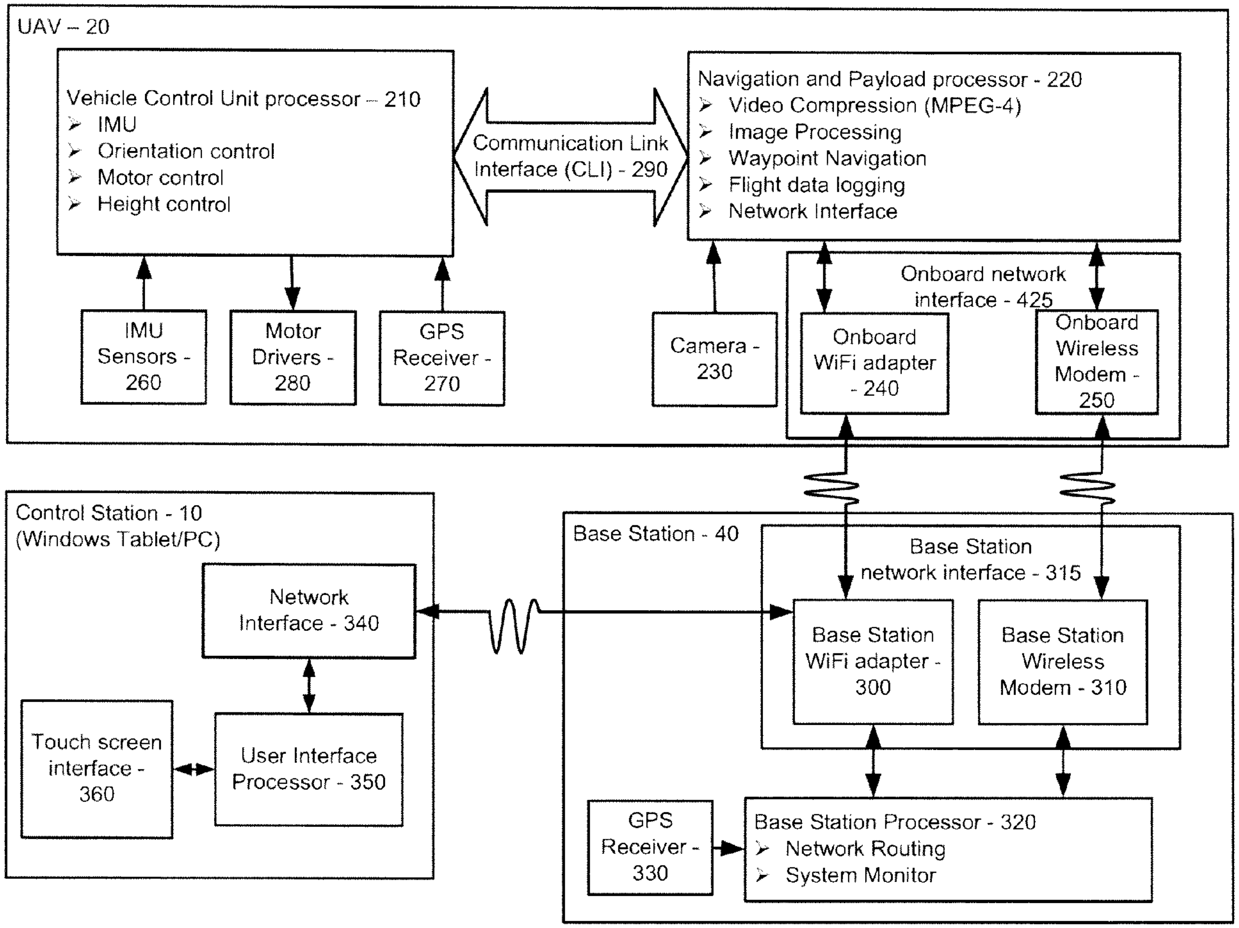

UAV – 20
Vehicle Control Unit processor – 210
➢ IMU
➢ Orientation control
➢ Motor control
➢ Height control
Communication Link Interface (CLI) - 290
Navigation and Payload processor - 220
➢ Video Compression (MPEG-4)
➢ Image Processing
➢ Waypoint Navigation
➢ Flight data logging
➢ Network Interface
IMU Sensors - 260
Motor Drivers - 280
GPS Receiver - 270
Camera - 230
Onboard network interface - 425
Onboard WiFi adapter - 240
Onboard Wireless Modem - 250
Control Station - 10 (Windows Tablet/PC)
Network Interface - 340
Touch screen interface - 360
User Interface Processor - 350
Base Station - 40
Base Station network interface - 315
Base Station WiFi adapter - 300
Base Station Wireless Modem - 310
GPS Receiver - 330
Base Station Processor - 320
➢ Network Routing
➢ System Monitor

FIG. 4

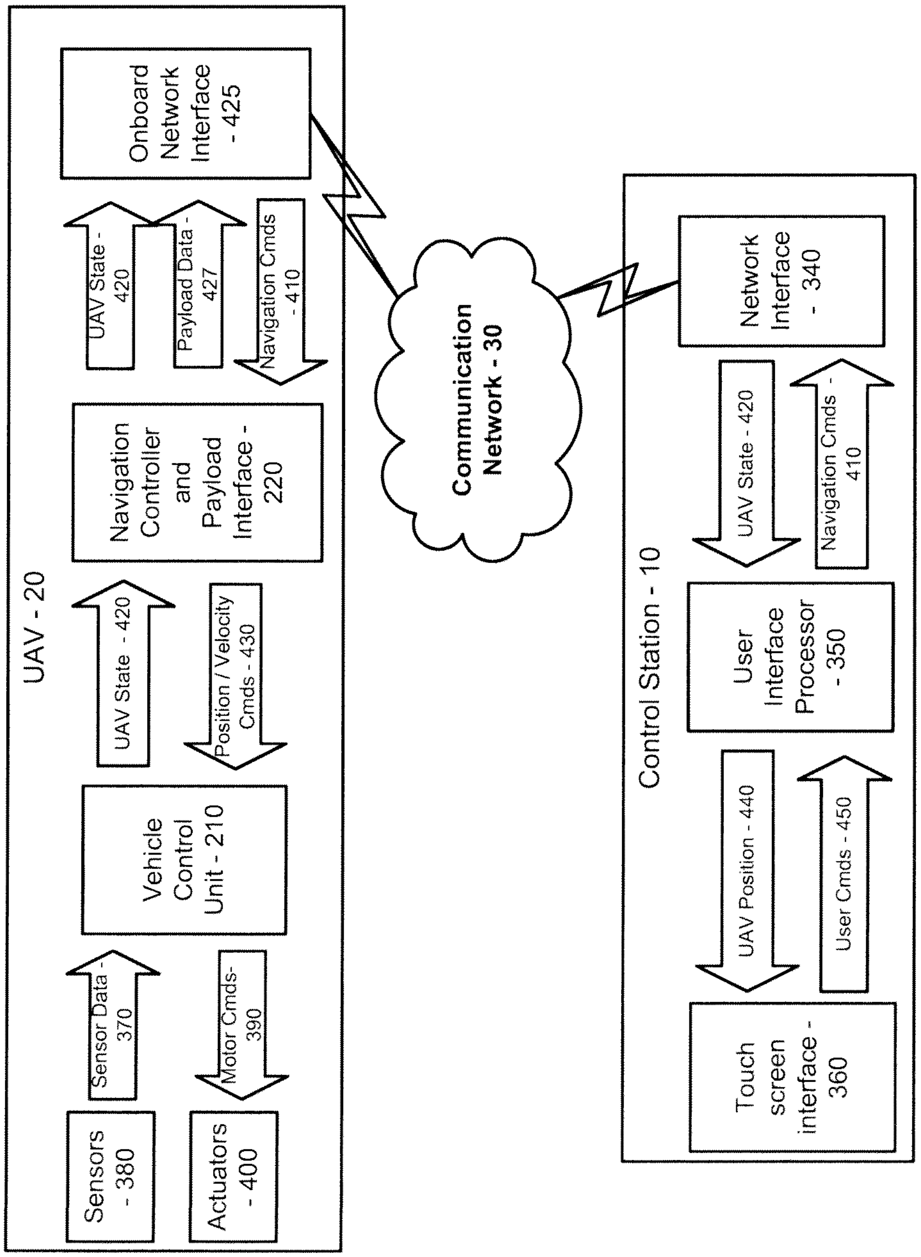

UAV - 20
Onboard Network Interface - 425
UAV State - 420
Payload Data - 427
Navigation Cmds - 410
Navigation Controller and Payload Interface - 220
UAV State - 420
Position / Velocity Cmds - 430
Vehicle Control Unit - 210
Sensor Data - 370
Motor Cmds- 390
Sensors - 380
Actuators - 400
Communication Network - 30
Control Station - 10
Network Interface - 340
UAV State - 420
Navigation Cmds - 410
User Interface Processor - 350
UAV Position - 440
User Cmds - 450
Touch screen interface - 360

FIG. 5

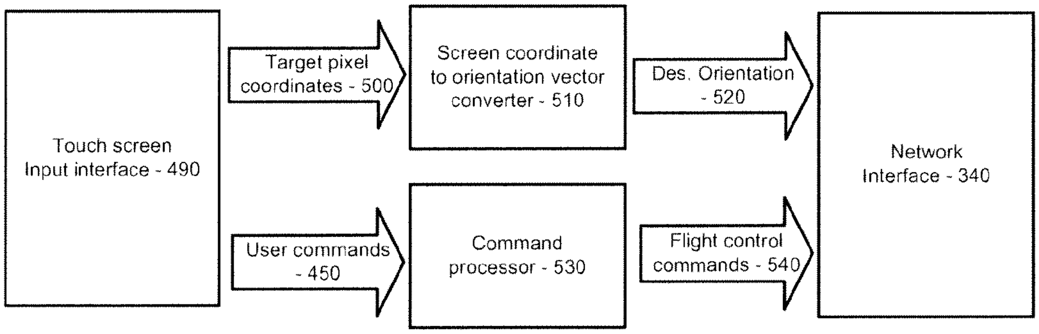

Touch screen Input interface - 490
Target pixel coordinates - 500
User commands - 450
Screen coordinate to orientation vector converter - 510
Command processor - 530
Des. Orientation - 520
Flight control commands - 540
Network Interface - 340

FIG. 6

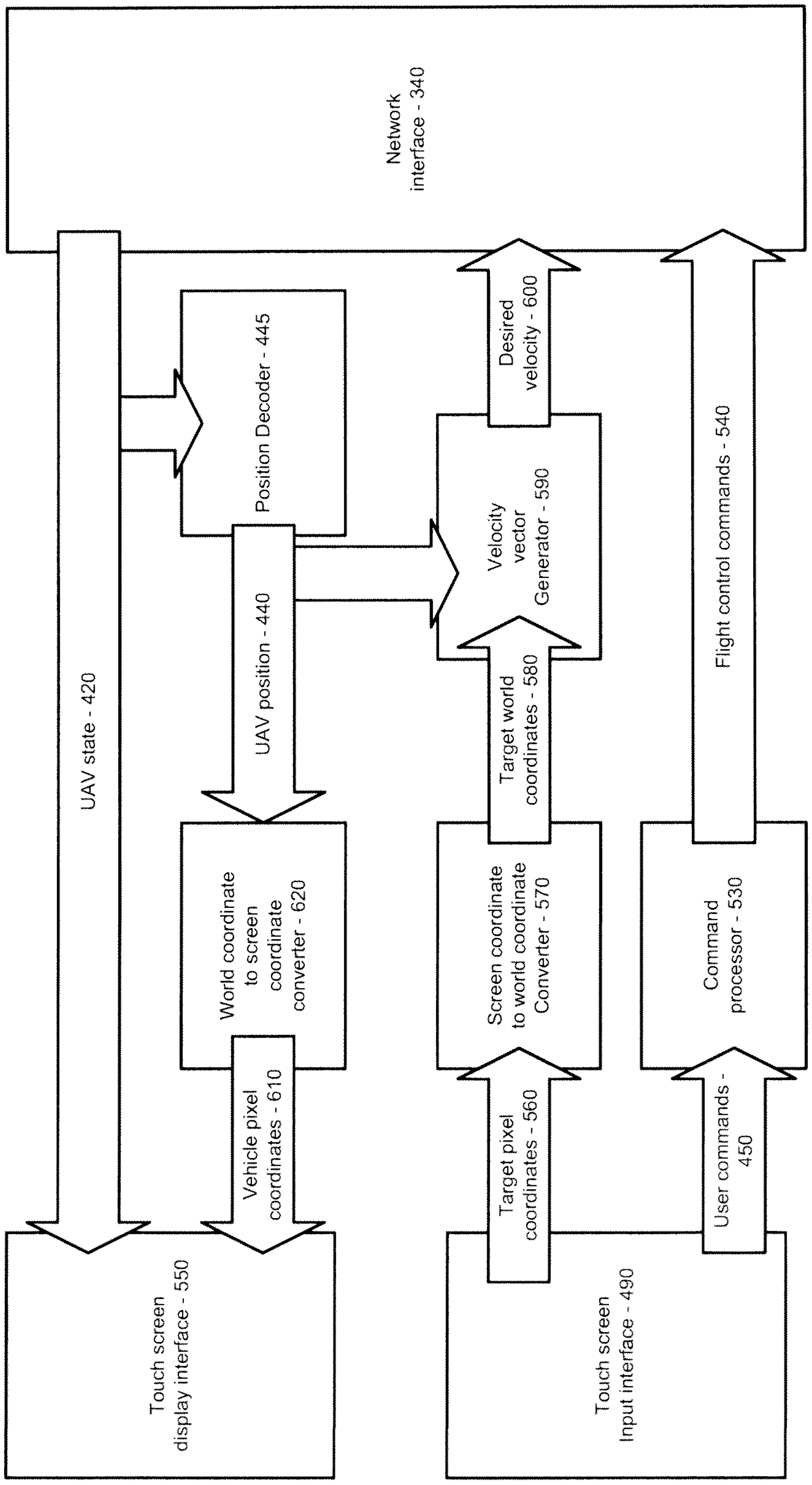

Network interface - 340
UAV state - 420
Position Decoder - 445
Desired velocity - 600
Flight control commands - 540
Velocity vector Generator - 590
UAV position - 440
Target world coordinates - 580
World coordinate to screen coordinate converter - 620
Screen coordinate to world coordinate Converter - 570
Command processor - 530
Vehicle pixel coordinates - 610
Target pixel coordinates - 560
User commands - 450
Touch screen display interface - 550
Touch screen Input interface - 490

FIG. 7

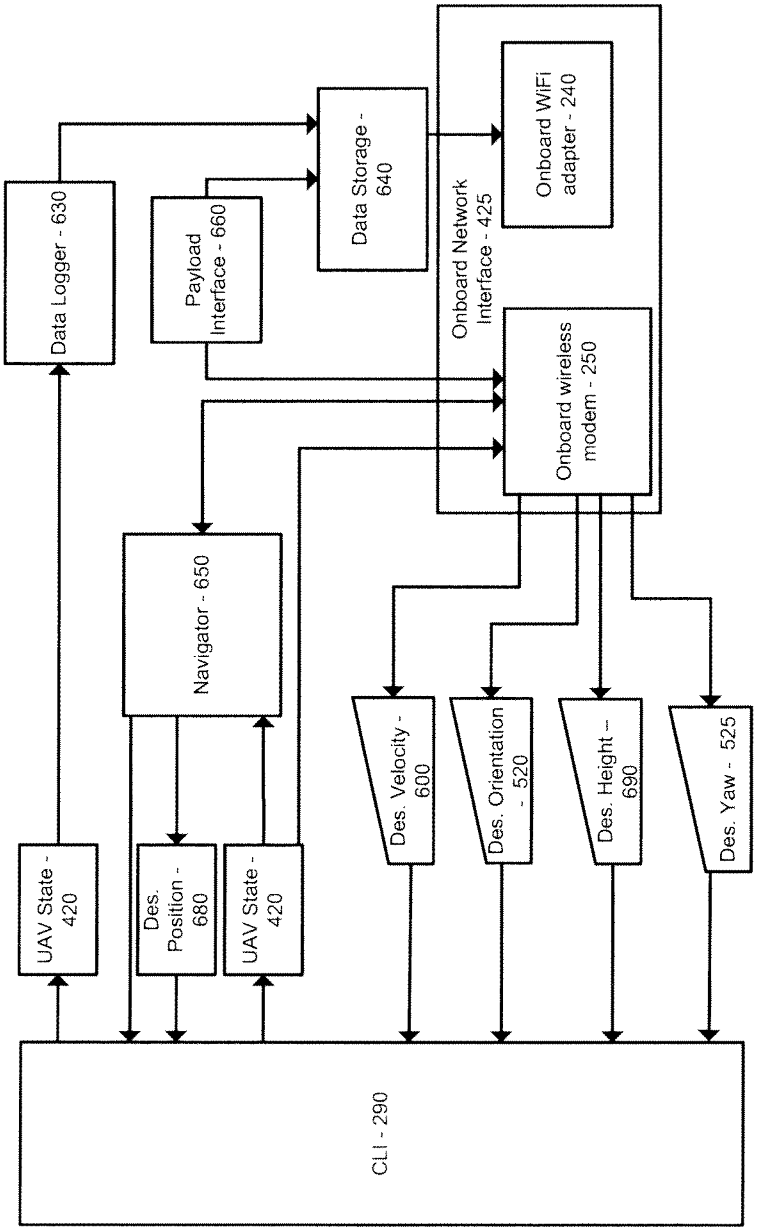

Data Logger - 630
Payload Interface - 660
Data Storage - 640
Onboard Network Interface - 425
Onboard WiFi adapter - 240
Onboard wireless modem - 250
Navigator - 650
UAV State - 420
Des. Position - 680
UAV State - 420
Des. Velocity - 600
Des. Orientation - 520
Des. Height – 690
Des. Yaw - 525
CLI - 290

FIG. 8

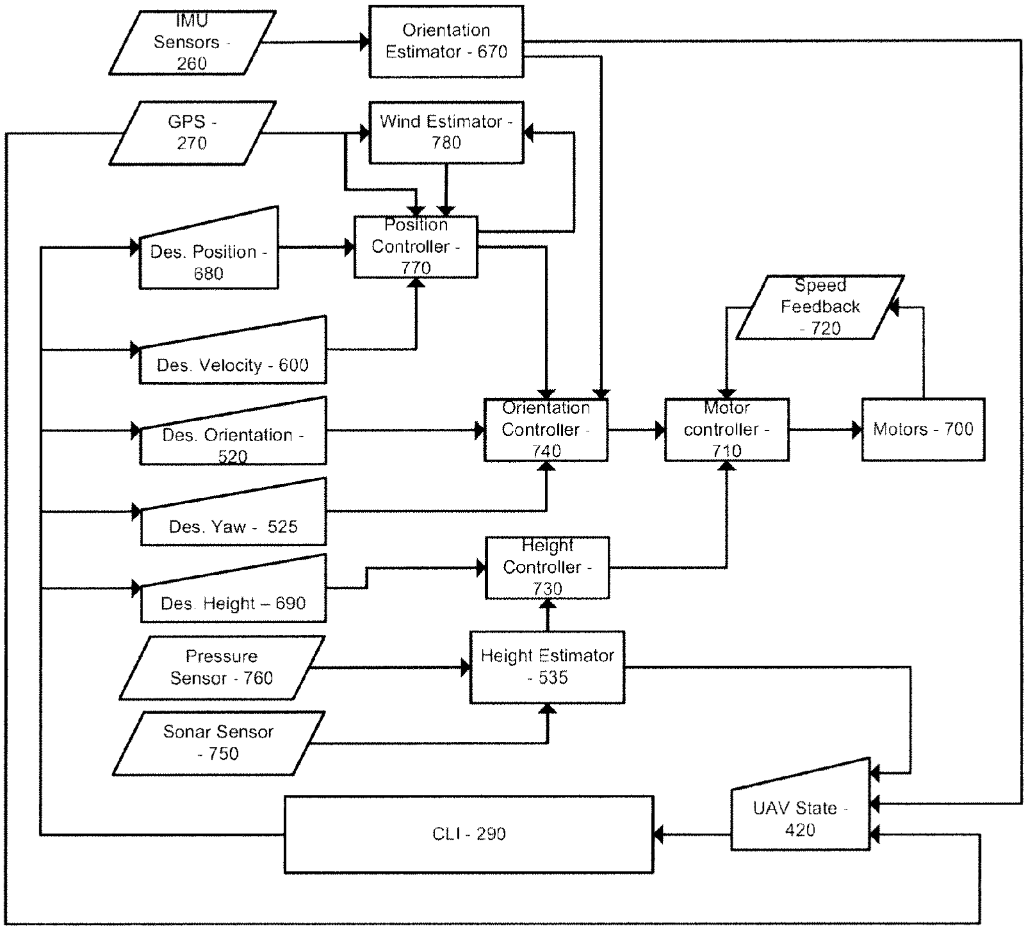

IMU Sensors - 260
Orientation Estimator - 670
GPS - 270
Wind Estimator - 780
Des. Position - 680
Position Controller - 770
Speed Feedback - 720
Des. Velocity - 600
Des. Orientation - 520
Orientation Controller - 740
Motor controller - 710
Motors - 700
Des. Yaw - 525
Height Controller - 730
Des. Height – 690
Pressure Sensor - 760
Height Estimator - 535
Sonar Sensor - 750
UAV State - 420
CLI - 290

FIG. 9

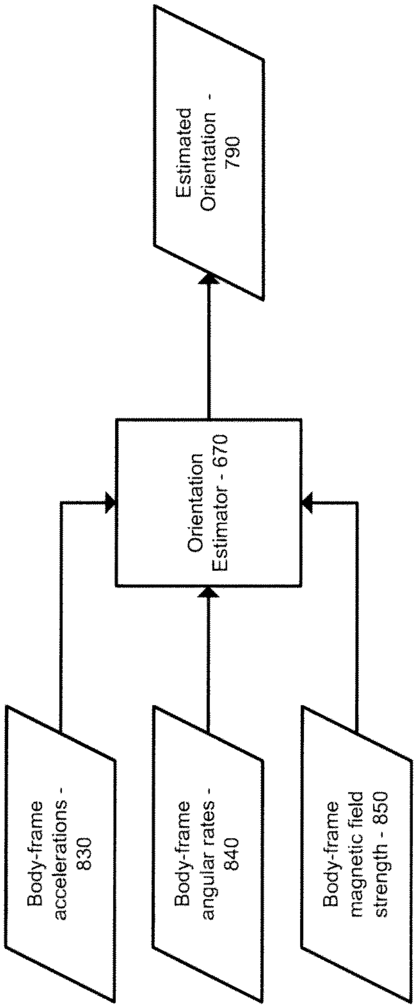

Body-frame accelerations - 830
Body-frame angular rates - 840
Body-frame magnetic field strength - 850
Orientation Estimator - 670
Estimated Orientation - 790

FIG. 10

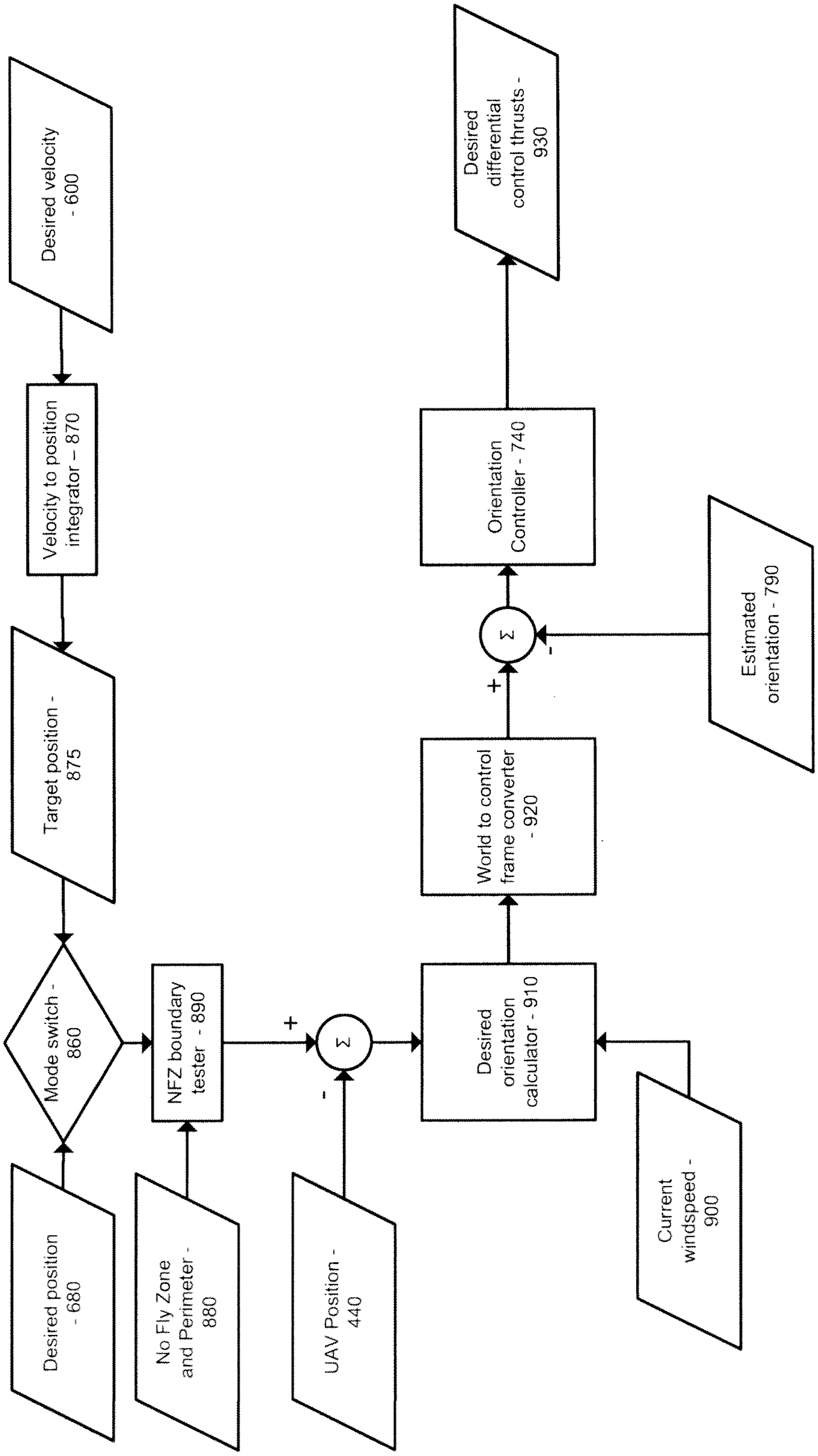

Desired position - 680
Mode switch - 860
Target position - 875
Velocity to position integrator – 870
Desired velocity - 600
No Fly Zone and Perimeter - 880
NFZ boundary tester - 890
UAV Position - 440
+
-
Σ
Desired orientation calculator - 910
World to control frame converter - 920
+
Σ
-
Orientation Controller - 740
Desired differential control thrusts - 930
Current windspeed - 900
Estimated orientation - 790

FIG. 11

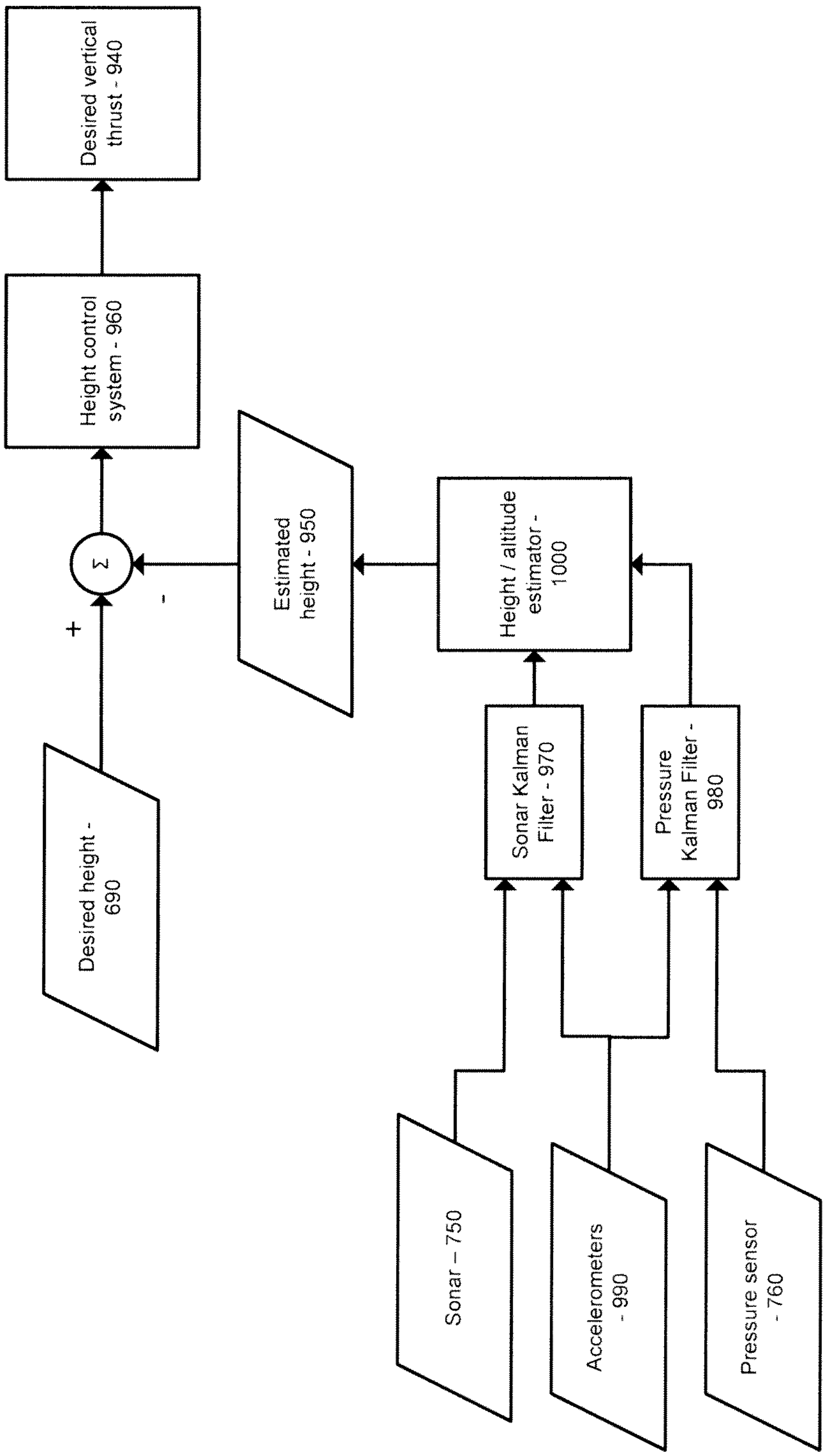

Desired height - 690
+
Σ
-
Height control system - 960
Desired vertical thrust - 940
Estimated height - 950
Height / altitude estimator - 1000
Sonar Kalman Filter - 970
Pressure Kalman Filter - 980
Sonar – 750
Accelerometers - 990
Pressure sensor - 760

FIG. 12

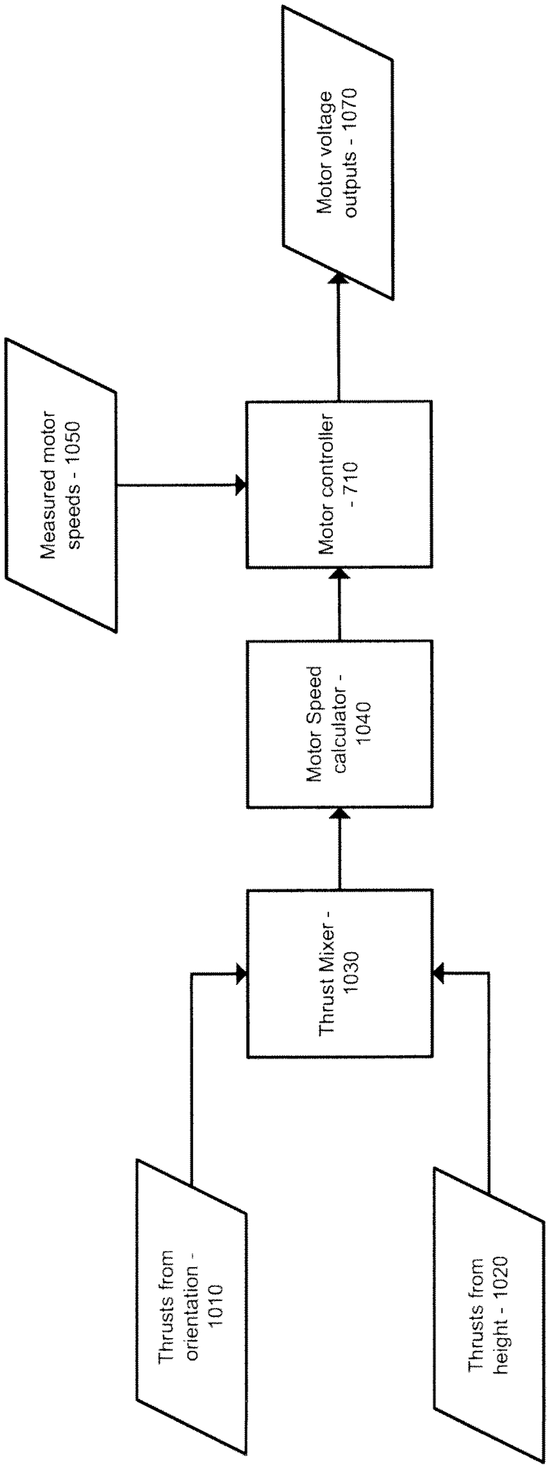
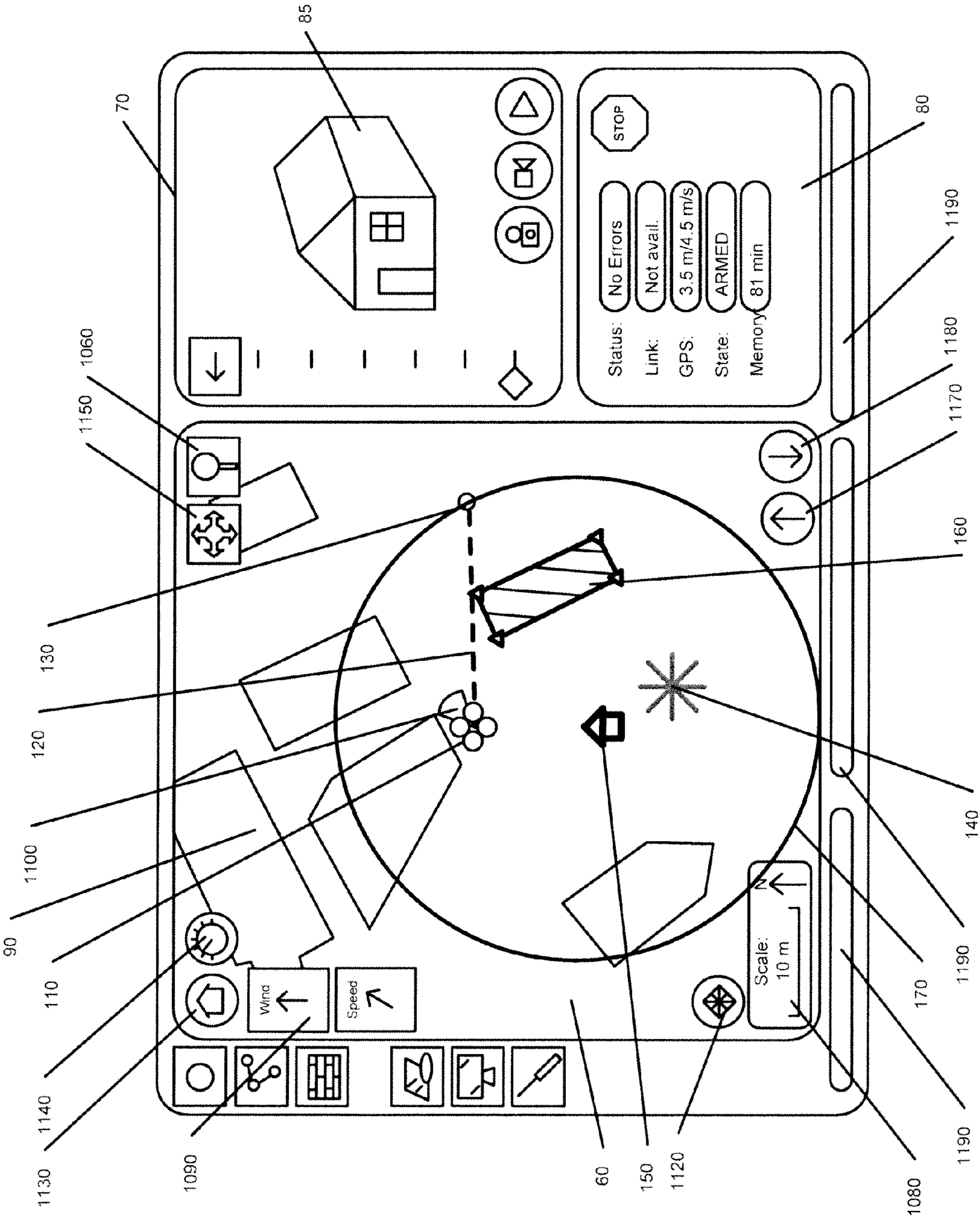

Thrusts from orientation - 1010
Thrusts from height - 1020
Thrust Mixer - 1030
Motor Speed calculator - 1040
Measured motor speeds - 1050
Motor controller - 710
Motor voltage outputs - 1070

FIG. 13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Memory: 81 min

FIG. 14

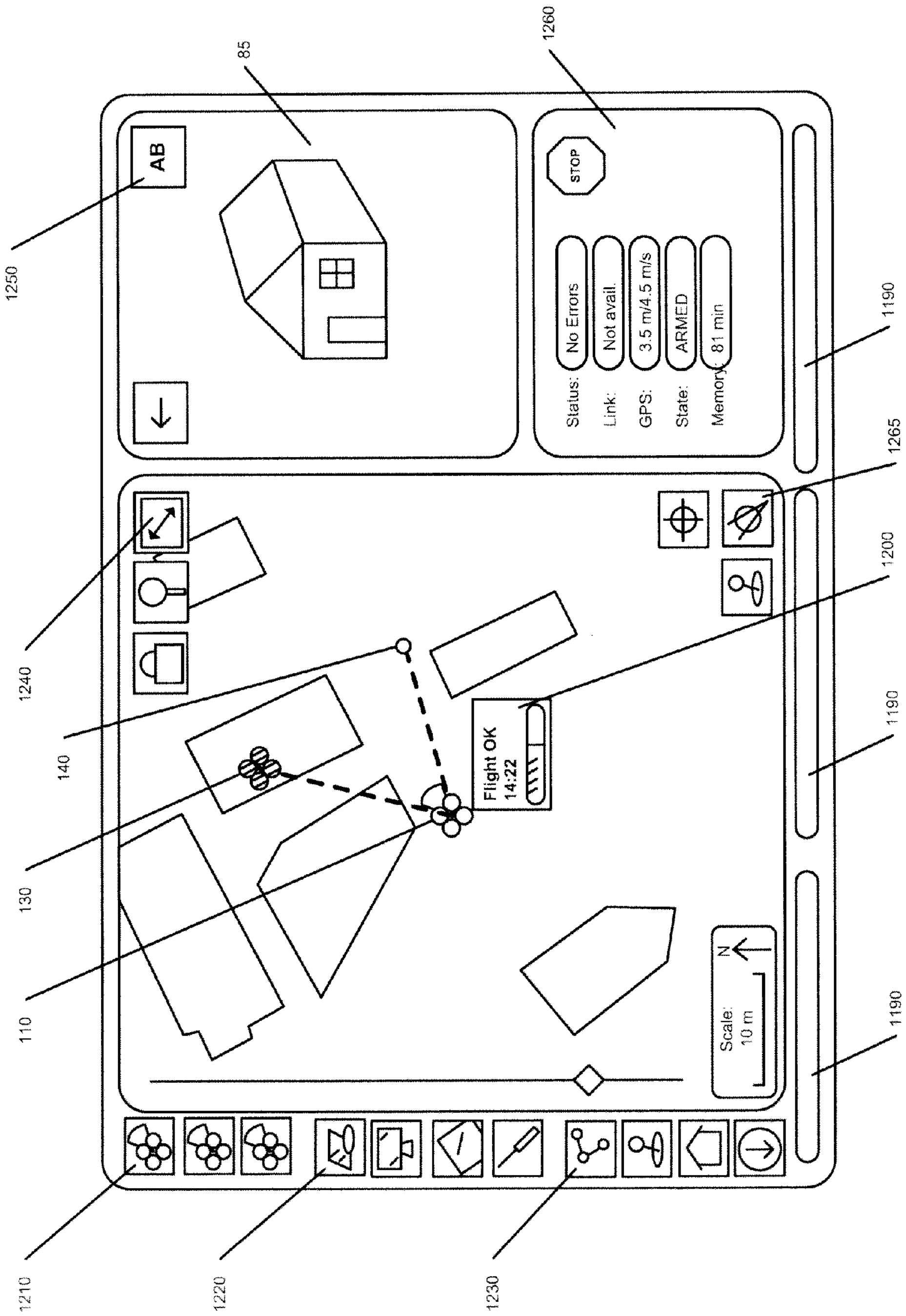

85
1260
1250
AB
STOP
Status: No Errors
Link: Not avail.
GPS: 3.5 m/4.5 m/s
State: ARMED
Memory: 81 min
1190
1265
1200
1240
140
130
110
Flight OK
14:22
1190
1190
Scale:
10 m
N
1210
1220
1230

FIG. 15

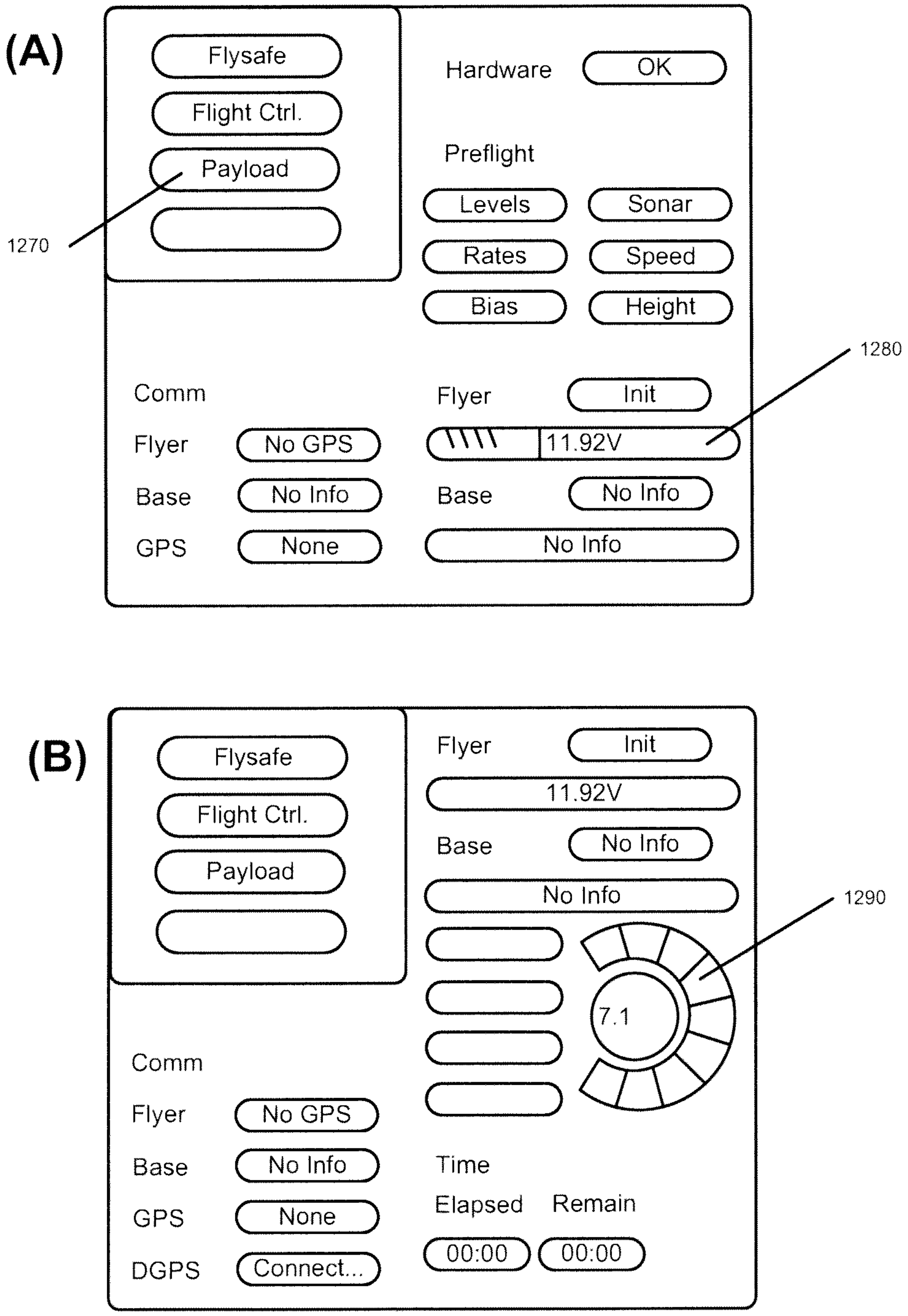
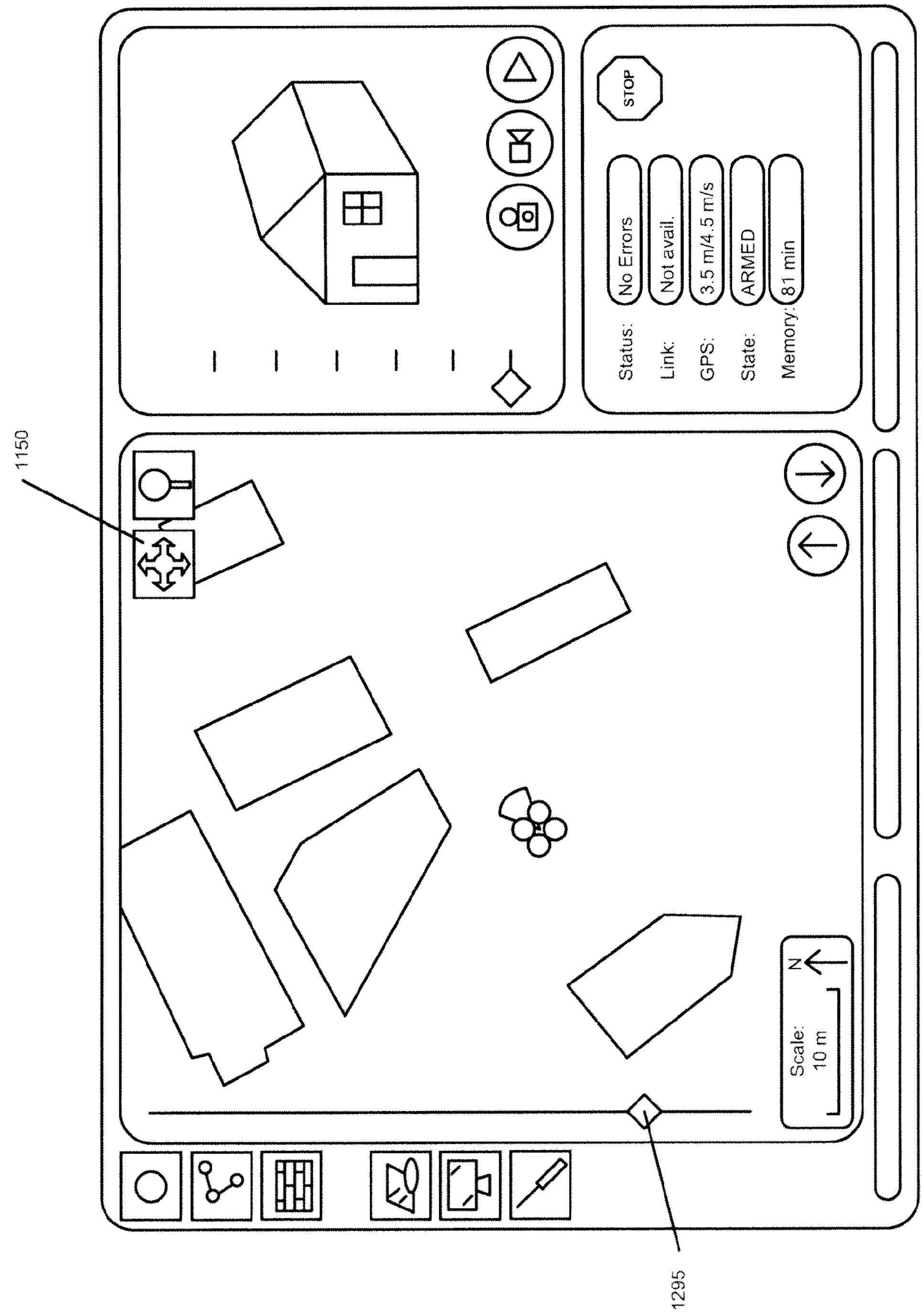

(A)
Flysafe
Flight Ctrl.
Payload
1270
Hardware
OK
Preflight
Levels
Sonar
Rates
Speed
Bias
Height
1280
Comm
Flyer
No GPS
Base
No Info
GPS
None
Flyer
Init
11.92V
Base
No Info
No Info
(B)
Flysafe
Flight Ctrl.
Payload
Flyer
Init
11.92V
Base
No Info
No Info
1290
7.1
Comm
Flyer
No GPS
Base
No Info
GPS
None
DGPS
Connect...
Time
Elapsed
Remain
00:00
00:00

FIG. 16



Status: No Errors

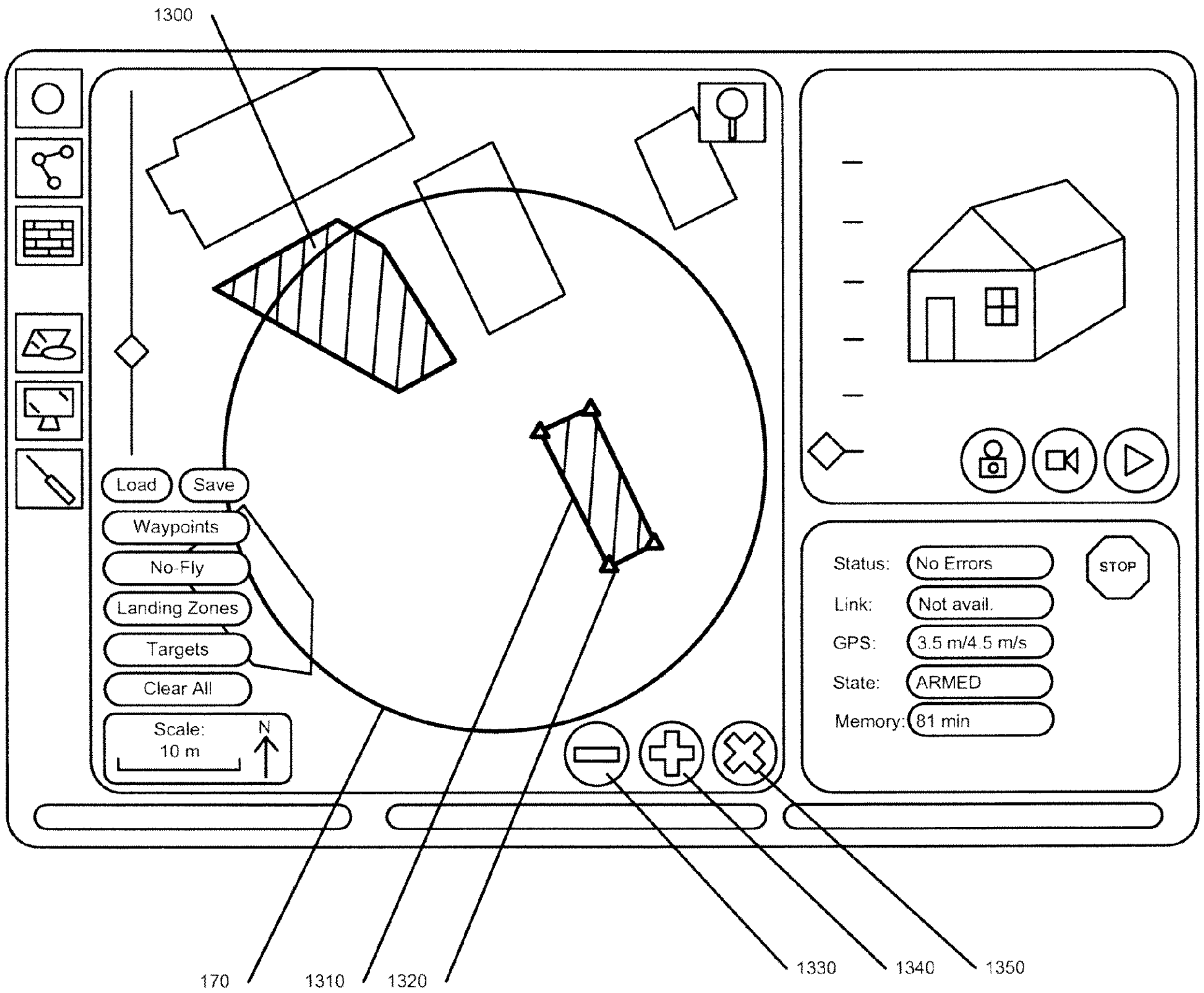
Link: Not avail.

GPS: 3.5 m/4.5 m/s

State: ARMED

Memory: 81 min

FIG. 17



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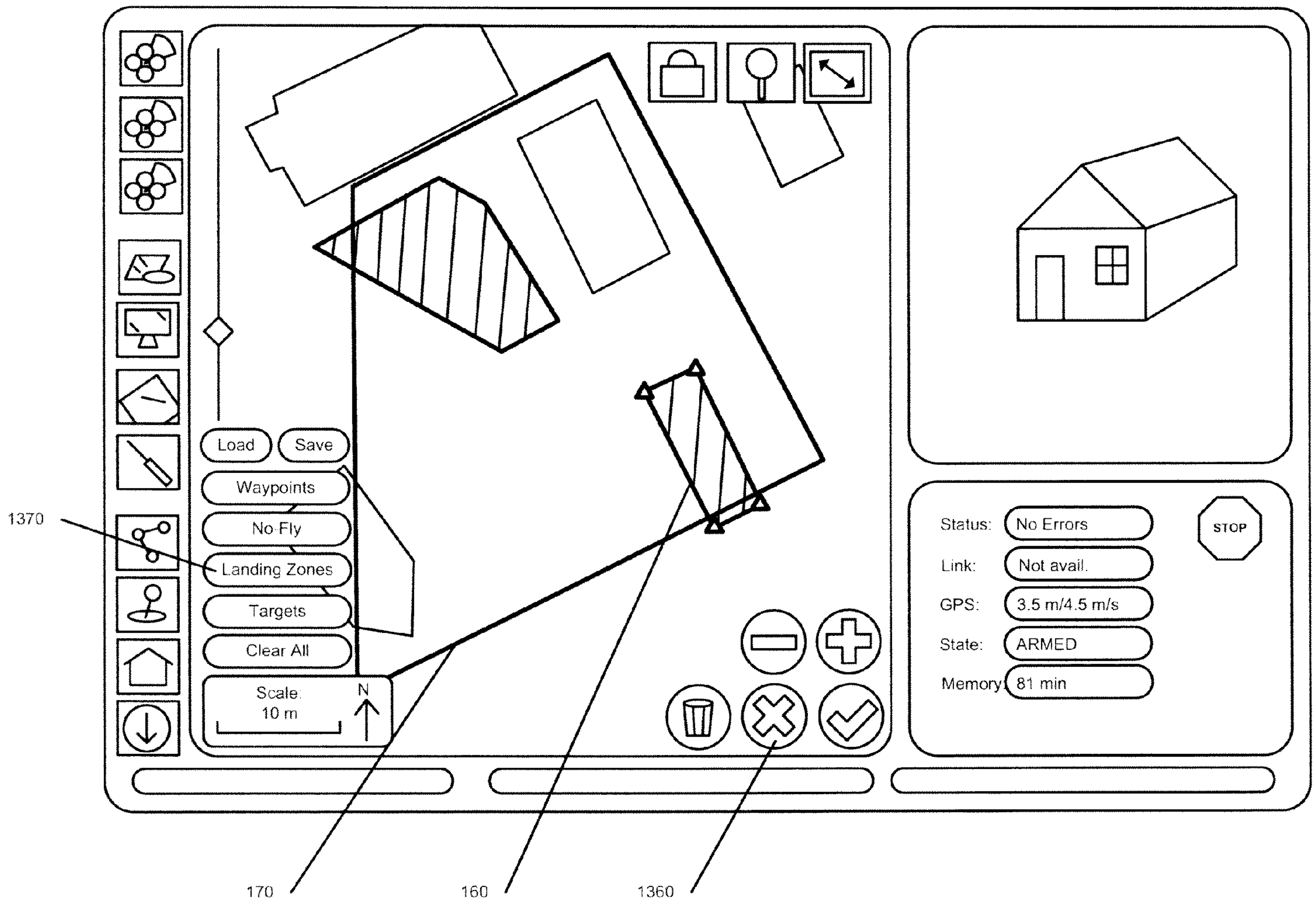
Link: Not avail.

GPS: 3.5 m/4.5 m/s

State: ARMED

Memory: 81 min

FIG. 18



Status: No Errors

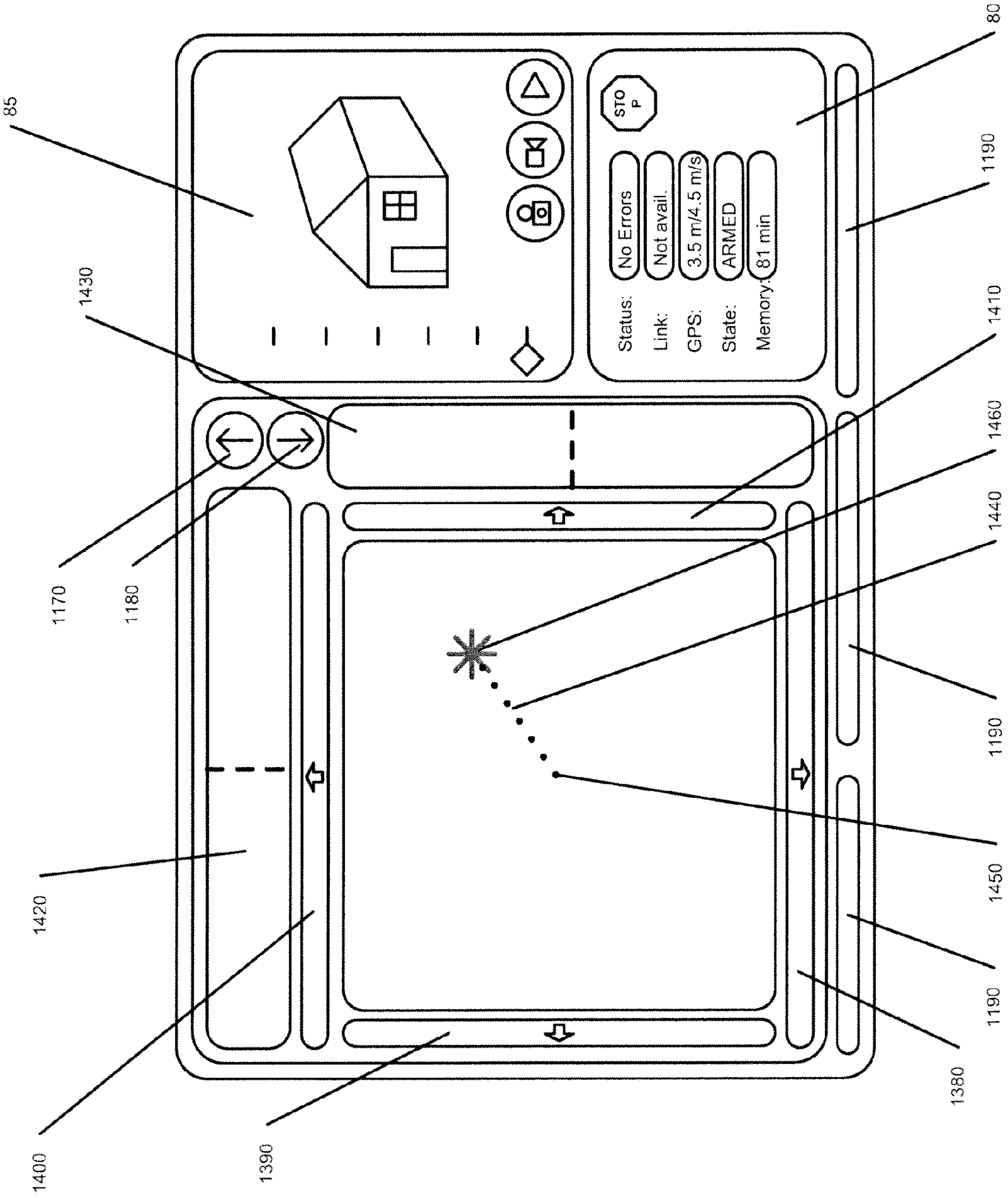
Link: Not avail.

GPS: 3.5 m/4.5 m/s

State: ARMED

Memory: 81 min

FIG. 19



Status: No Errors
Link: Not avail.
GPS: 3.5 m/4.5 m/s
State: ARMED
Memory: 81 min

FIG. 20

METHOD AND SYSTEM FOR DIRECTING UNMANNED VEHICLES

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of priority of U.S. Provisional Patent Application No. 61/191,426 filed Sep. 9, 2008, which is incorporated herein by reference in its entirety.

FIELD

The present application relates generally to command and control of unmanned aerial vehicles ("UAVs"). More particularly, the present application relates to a simple and intuitive control method and system for a single or multiple UAV system, where each UAV can have a varying degree of autonomy.

BACKGROUND

Remote-controlled UAVs with camera capability have been known for many years. UAVs are used to provide visual reconnaissance for areas which are typically inaccessible by humans. These types of UAVs include a hovering UAV which is lifted and controlled by independently driven rotors or propellers. By varying the thrust generated by each of the rotors, the orientation and speed of the UAV can be controlled. Various designs have been proposed for such a UAV, the primary requirement of which is to rigidly mount the rotors at fixed distances from the center of the craft, while minimizing the weight of the structure.

Use of a hovering UAV is especially effective for providing digital imagery or real-time digital video from aerial vantage points. For instance, first responders to a natural disaster or train derailment can benefit from this aerial vantage point to help determine the imminent danger of the situation. Alternatively, a hovering UAV can also be used as a security measure to provide a mobile, airborne security system.

Direct manual control of a hovering UAV requires a great deal of skill and training, and controlling a hovering UAV in such a way requires the user's constant undivided attention. Thus, automation in stabilizing and maintaining flight of a hovering UAV is desirable and has been known for many years. However, directing the course of such an automated hovering UAV may remain challenging and require skill and training in order to make effective use of a hovering UAV.

U.S. Pat. No. 6,694,228, issued on Feb. 17, 2004 to Rios, teaches a control system for a UAV that includes control translations. The system taught by Rios maximizes operational employment of the UAV payload. By determining spatial references, and then using the references to transform the control stick commands, the operator treats the UAV as a point source. For control through imagery from onboard mission sensors, the transformations provide for the UAV to move itself and achieve payload orientation.

It is, therefore, desirable to provide a simplified user-interface that allows a user with little or no training or experience, e.g. no special skills, to effectively operate a hovering UAV or group of hovering UAVs, and which further allows such a user to control multiple partially-automated functions of one or more hovering UAVs within a group of hovering UAVs.

SUMMARY

It is an object herein to obviate or mitigate at least one disadvantage of previous methods and systems of directing or navigating an aerial vehicle.

The present application is intended to provide an intuitive method for planning, executing, and reviewing missions undertaken by a single or multiple hovering UAV system, where each hovering UAV may be capable of a dynamically-varying level of autonomy. Methods are provided to allow full mission planning and control on a variety of controller form factors with a multitude of input methods, allowing for a high degree of system flexibility and mobility of the system users. The control interface provides the ability to set boundaries and exclusion zones in concert with the designation of preferred routes, target locations, and home positions. The method causes UAVs to autonomously override operator instructions if it is determined that they would otherwise pass into one of the user-defined restricted areas. The control interface also provides the ability to set desired locations the system should be interacting with/observing, areas which UAVs should return to upon mission completion or system failure, and predetermined preferred routes. The user is able to modify all of these aspects before, during, and after the execution of the mission. Performing these operations in parallel allows mission plans to be developed, deployed, and modified quickly. The stateless, integrated design allows for switching between vehicles in different modes of operation while still providing important data on the status of the entire system, increasing the ease-of-use of the system and improving the ability of the supervisor to effectively control multiple vehicles.

Individual UAVs controlled by the method herein described may be in different states from each other at any given time during system operation and may thus require the user to perform different tasks, those tasks not being limited to navigating or directly controlling the UAVs. Examples of such tasks include pre-mission checks, UAV configuration, mission execution, on-line mission modification, manual override, and post-mission review. Where a multitude of UAVs are being controlled, the user may need to quickly switch between UAVs in different modes. The system does not hinder the operator in this task, whether by requiring the switching of control methods, communication settings, or the performance of other extraneous tasks.

The deployment of this system may be for a task which does not allow the transportation or operation of a great deal of support infrastructure. It is therefore advantageous that the user is able to operate the entire system from a device with a small form factor, such as a sufficiently capable smartphone or a small tablet PC. For ease of use, the method for system control and the graphical user interface ("GUI") may be consistent across the range of possible devices.

The control method herein is intended to be flexible enough to design missions with a reasonable amount of complexity, while still being simple enough to operate via a point-and-touch interface on a mobile device. The control method further combines a high level of vehicle automation with intuitive user controls and displays such that a substantial reduction in the required skill level and training of the user is achieved.

In a first aspect, there is provided a method of remotely controlling an aerial vehicle within an environment, including providing a control station in communication with the aerial vehicle, providing a visual representation of the environment (such as a map or aerial view), receiving target world coordinates for the aerial vehicle within the environment, determining a desired velocity vector to direct the aerial vehicle to the target world coordinates, and directing the aerial vehicle along the desired velocity vector until the aerial vehicle reaches the target world coordinates.

In one embodiment, the desired velocity vector includes a speed proportional to the distance between the aerial vehicle and the target world coordinates.

In one embodiment, the method further includes directing the aerial vehicle to cease travelling to the target world coordinates and to remain at a current position if the user ceases to provide input providing target world coordinates.

In one embodiment, the method further includes recalculating the desired velocity vector as the aerial vehicle travels towards the target world coordinates to reduce the speed of the aerial vehicle as it approaches the target world coordinates.

In one embodiment, the method further includes automatically directing the aerial vehicle to remain at a current position if to continue travelling along the desired velocity vector would otherwise direct the aerial vehicle into a no-fly zone.

In one embodiment, the method further includes automatically directing the aerial vehicle to remain at a current position prior to beginning to travel along the vector if to travel along the vector would at any point direct the aerial vehicle into a no-fly zone.

In one embodiment, the method further includes automatically directing the aerial vehicle to remain at a current position if to continue travelling along the desired velocity vector would otherwise direct the aerial vehicle outside a perimeter.

In one embodiment, the method further includes automatically directing the aerial vehicle to remain at a current position prior to beginning to travel along the vector if to travel along the vector would at any point direct the aerial vehicle outside a perimeter.

In one embodiment, the method further includes selecting a maximum speed which the aerial vehicle will not exceed.

In one embodiment, the method further includes directing the aerial vehicle to take an action upon reaching the target world coordinates.

In one embodiment, the method further includes controlling one or more functions of one or more of the aerial vehicles by multiple control stations.

In one embodiment, the target world coordinates are received by a graphical user interface. In one embodiment, the graphical user interface is a touch interface for use with a users finger or a stylus etc.

In one embodiment, the user provides the target world coordinates by touching a target position icon on the visual representation of the environment. While the user provides the target world coordinates by touching a point on the map, the UAV travels to the target world coordinates corresponding to the point.

In one embodiment, the aerial vehicle remains at a current position if the user ceases to touch the target position icon. If the user ceases to touch the target position icon on the map, the UAV stops moving towards the target world coordinates and hovers in place.

In one embodiment, the method further includes defining a flight parameter within the environment. In one embodiment, the flight parameter is selected from the group of a no-fly zone, a perimeter, a target, a home location, or a combination thereof. In one embodiment, the flight parameter is polygonal or circular in shape.

In one embodiment, the method further includes providing a sensory payload on the aerial vehicle, and transmitting data gathered by the sensory payload, directly or indirectly, to the control station.

In one embodiment, the method further comprises controlling the sensory payload independently of the aerial vehicle.

In one embodiment, the method further comprises directing a plurality of aerial vehicles from the control station.

Other aspects and features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will now be described, by way of example only, with reference to the attached Figures, wherein:

FIG. **1** is a schematic of the overall architecture of the network connections for use with the present invention;

FIG. **2** is a screenshot from a first GUI that may be used to implement the method of the present invention;

FIG. **3** is a schematic of three coordinate frames that navigate a UAV;

FIG. **4** is a schematic of one embodiment of hardware components to implement the method, and of the function of the hardware components;

FIG. **5** is a schematic of communication between hardware components which implement the method of the present invention;

FIG. **6** is a schematic of logic that may be used to generate a desired orientation vector from user input on a touch-screen input interface when manually controlling flight of the UAV;

FIG. **7** is a schematic of map interface logic for both a touch-screen display interface and the touch-screen input interface when directing flight of the UAV through velocity vectors;

FIG. **8** is a schematic of high-level functional blocks of software components executing on a navigation and payload processor, and flow of data between the software components, and between the software components and associated hardware;

FIG. **9** is a schematic of high-level functional blocks of software components executing on a vehicle control unit processor, and flow of data between the software components, and between the software components and associated hardware;

FIG. **10** is a flow chart of high-level functional blocks of software components executing on a UAV orientation estimator;

FIG. **11** is a flow chart of high-level functional blocks of software components executing on a UAV position controller and orientation controller;

FIG. **12** is a schematic of high-level functional blocks of software components executing on a UAV height controller, and flow of data between the software components, and between the software components and associated hardware;

FIG. **13** is a flow chart of high-level functional blocks of software components executing on a UAV motor speed controller;

FIG. **14** is a screenshot from the first GUI in a "press and hold" velocity input mode;

FIG. **15** is a screenshot from a second GUI that may be used to implement the method in a "press and hold" velocity input mode;

FIGS. **16**(*a*) and **16**(*b*) are screenshots from the second GUI illustrating changes in display that occur upon changing a control mode of the UAV;

FIG. **17** is a screenshot from the first GUI in a "map-panning mode";

FIG. **18** is a screenshot from the first GUI in a "mission edit" mode;

FIG. **19** is a screenshot from the second GUI in a "mission edit" mode; and

FIG. **20** is a screenshot from the first GUI being used to control the UAV's orientation directly.

DETAILED DESCRIPTION

Communication Network

FIG. **1** is a schematic of the overall architecture of the network connections for use with the present embodiment. A control station **10** is in wireless communication with a UAV **20** via a communication network **30**. While only one UAV **20** is pictured in FIG. **1** and referred to in the following figures, the method also applies to a plurality of UAVs **20** or a plurality of control stations **10** or both. The communication network **30** may include direct communication between the control station **10** and the UAV **20**, or a base station **40** may form an intermediary link in the communication network **30**, relaying information between the control station **10** and the UAV **20**.

The UAV **20** may be any of a number of types of UAVs, but is preferably a rotor-driven UAV of the type described in U.S. patent application Ser. No. 12/465,912, filed May 14, 2009. The UAV **20** is also preferably capable of hovering in a fixed location by automatically adjusting output of the rotors present such that it takes into account and corrects for drift caused by wind or updrafts.

The control station **10** may be any one of a number of general purpose programmable computers or other user interface devices, but is preferably a handheld tablet with a responsive touch-screen. The control station preferably includes a visual display and may provide visual, auditory, and tactile feedback to the user. Functions of the UAV **20** may be controlled from the control station **10** in a simple and intuitive way.

The communication network **30** may also include optional devices such as a base station **40**, which may provide extended communication range, and may allow for enhanced localization accuracy of the UAV **20**, and an external display **50**, which may allow observation of sensor data from the payload of the UAV **20** or of a first GUI or second GUI (FIGS. **2** and **14-20**). The external display **50** may be any type of display apparatus, such as a standard computer monitor, television, head-mounted display, or 3-D visualization tool.

Graphical User Interface (GUI)

FIG. **2** is a screenshot from a first GUI that may be used to implement the method. The first GUI is divided into three broad sections: a map **60**, a payload window **70**, and a UAV status window **80**. The payload window **70** displays information obtained from the sensory payload, for example video feed **85** from a camera **230** (FIG. **4**). The UAV status window **80** displays information regarding status of various aspects of the UAV **20**, such as the status of network links, estimated accuracy of a position estimate provided by a global positioning system ("GPS"), and an amount of available data storage **640** (FIG. **8**).

Some of the features of the map **60** are shown in FIG. **2**; additional features are described below in relation to FIG. **14**. The map **60** is a top-down view of the environment in which the UAV **20** is operating and may be obtained from a variety of sources, including satellite feed or a web-based map service. Both man-made features, for example a building **90**, and natural features, for example a tree **100**, may be visible. Several icons may also be present on the map **60**. A UAV icon **110** indicates the position and orientation of the UAV **20**. The straight-line path **120** is between the current position of the UAV **20** as indicated by the UAV icon **110**, and a target position icon **130**, which indicates a target position **875** of a desired velocity vector **600** (FIG. **11**) of the UAV **20**. A user defines the desired velocity vector **600**, and the target position icon **130** and straight-line path **120** is automatically generated.

A sensory payload, such as the camera **230** (FIG. **4**) may automatically track to a target **140**. The UAV **20** may be directed to automatically proceed to a home location **150**. A no-fly zone ("NFZ") **160** and a perimeter **170** are also shown on the map **60**. The UAV **20** cannot enter the NFZ **160** or leave the perimeter **170**. The UAV **20** will automatically stop and maintain its position if to continue along its straight-line path **120** would cause it to enter the NFZ **160** or leave the perimeter **170**. Flight parameters may include the target **140**, the home location **150**, the NFZ **160**, the perimeter **170**, and a waypoint **1470** (FIG. **19**) may be designed and modified by the user with the control station **10** during or prior to operation of the UAV **20**. A combination of flight parameters may define a flight plan, and the flight plan may be designed and modified by the user with the control station **10** during or prior to operation of the UAV **20**.

UAV Navigation

FIG. **3** is a schematic of three coordinate frames that navigate the UAV **20**. A global frame **180** defines a coordinate system relative to a fixed point on the surface of the Earth, defined by orthogonal vectors pointing North, East, and Down (N, E, D). The position and velocity of the UAV **20** are controlled with respect to the global frame **180**. The orientation of the UAV **20** is defined by a body frame **190**, defined by the vectors (x, y, z) pointing from the centre of mass toward the front, right, and bottom of the UAV **20**. The roll and pitch of the UAV **20** are shown by comparison to a control coordinate frame **200** in which the (x', y') plane is parallel to the (N, E) plane in the global frame **180**.

Hardware

FIG. **4** is a schematic of one embodiment of hardware components to implement the method, and of the function of the hardware components. The UAV **20** includes 2 logical processing components: a vehicle control unit processor **210** and a navigation and payload processor **220**. A communication link interface ("CLI") **290** allows communication between the vehicle control unit processor **210** and the navigation and payload processor **220**.

The navigation and payload processor **220** performs waypoint navigation, interfaces with payload sensors, and interfaces with the communication network **30** through an onboard network interface **425**. Payload sensors commonly include a camera **230**, although the payload sensors could also include sensors adapted to detect audio, temperature, biomolecules, or any other target stimulus. The onboard network interface **425** may include an onboard WiFi™ adaptor **240** and an onboard wireless modem **250**. The vehicle control unit processor **210** may receive input from inertial measurement ("IMU") sensors **260**, and an onboard GPS receiver **270**, and controls the controls the position and the orientation of the UAV **20** via motor drivers **280**. The IMU sensors preferably include a 3-axis accelerometer, a 3-axis rate gyroscope, and a 3-axis magnetometer.

The base station **40** may include a base network interface **315** which interfaces with the communication network **30**. The base network interface **315** may include a base station WiFi™ adaptor **300** and base station wireless modem **310**. The base station **40** may also include a base station processor **320** to support network routing and system monitoring, and may include a base station GPS receiver **330** to augment localization of the UAV **20**.

The control station **10** may include a network interface **340** to communicate a user interface processor **350**, and a touch-screen interface **360**. The network interface **340** may allow communication with the UAV **20** and base station **40** over the communication network **30**. The user interface processor **350** may process input from the user and information received from the communication network **30** via the network interface **340**. The touch-screen interface **360** may receive input from the user and provide visual feedback to the user.

All data sent over an onboard network interface **425** is preferably packetized by a protocol converter into transmitted data suitable for transmission over the communication network **30**. Conversely, all data received by the onboard network interface **425** is preferably depacketized by a protocol convertor for interpretation by the relevant processor. The same is true with respect to the base network interface **315** and the network interface **340**.

FIG. **5** is a schematic of the communication between hardware components which may be used to implement the method. On the UAV **20**, sensor data **370** may be captured from sensors **380** and sent to the vehicle control unit processor **210**, which in turn provides UAV state **420**. Sensors **380** may include IMU sensors **260**. The UAV state **420** may include the orientation, position, velocity, height, and motor speeds of the UAV **20**. The UAV state **420** is sent to the navigation and payload processor **220** (via the CLI **290**; FIG. **4**). The navigation and payload processor **220** sends both the UAV state **420** and payload data **427** through the onboard network interface **425** over the communication network **30** to the control station **10**. The payload data **427** may be received by the navigation and payload processor **220** from, for example, the camera **230** (FIG. **4**).

The control station **10** may receive the UAV state **420** from the communication network **30** at the network interface **340**. The user interface processor **350** may receive the UAV state **420** from the network interface **340** and based on the UAV state **420**, display a UAV position **440** as the UAV icon **110** at the corresponding location on the map **60** (FIG. **2**), which is shown on the first GUI of the touch-screen interface **360**.

User commands **450** may be received as presses on the touch-screen interface **360**. User commands **450** may correspond to any function of the UAV **20**. The user interface processor **350** may transform user commands **450** from pixel coordinates on the display into navigation commands **410**. Navigation commands **410** may include desired orientation **520** (FIG. **6**), desired velocity vector **600** (FIG. **7**), desired height **690** (FIG. **8**), and flight control commands **540** (FIG. **6**). Flight control commands **540** may include flying to a waypoint, taking off and landing, mode changes, and setting changes. Navigation commands **410** are communicated to the UAV **20** through the network interface **340** and communication network **30**. User commands **450** that are not transformed into navigation commands **410** may be sent over the communication network **30** in the same way as navigation commands **410**.

The UAV **20** receives navigation commands **410** from the communication network **30** via the onboard network interface **425**. The navigation and payload processor **220** receives the navigation commands **410** and converts them into position and velocity commands **430**, which are communicated to the vehicle control unit processor **210** (via the CLI **290**; FIG. **4**). The vehicle control unit processor **210** combines sensor data **370** with position and velocity commands **430** to generate motor commands **390** that will control the orientation of the UAV **20** by varying the speed of actuators **400**. The motor commands **390** will cause the UAV **20** to travel according to the navigation commands **410**.

Commands to Direct UAV

FIG. **6** is a schematic of logic that may be used to generate a desired orientation vector from user input on a touch-screen input interface **490** when manually controlling flight of the UAV **20**. Input through the touch-screen input interface **490** will generate either target pixel coordinates **500**, or user commands **450**, as determined by the portion of the first GUI at which the user provides input.

Target pixel coordinates **500**, are converted by the screen coordinate to orientation vector converter **510** into a desired orientation **520**, preferably expressed as roll and pitch. The desired orientation adjusts the roll, pitch or both of the UAV **20**, which is in the body frame **190** (FIG. **3**). A desired yaw **525** is included in the flight control commands **540**, generated from user commands **450** by touching the video panel or using the targeting icon button **1120** in map mode, or the manual yaw control icon **1420** in the indoor mode. This information is then sent through the network interface **340**. User commands **450** may be converted by a command processor **530** into flight control commands **540**. Each of the flight control commands **540** and the desired orientation **520** are sent to the UAV **20** over the communication network **30** (FIG. **1**) via the network interface **340**.

FIG. **7** is a schematic of map interface logic for both a touch-screen display interface **550** and the touch-screen input interface **490** when directing flight of the UAV **20** through velocity vectors. Target pixel coordinates **560** may be received through user input on the map **60** portion of the first GUI (FIG. **2**) displayed on the touch-screen input interface **490**. The target pixel coordinates **560** are processed by the screen coordinate to world coordinate converter **570** to generate target world coordinates **580**. The target world coordinates **580** and the UAV position **440** are the inputs required for the velocity vector generator **590**, which may generate a desired velocity vector **600**, preferably expressed as latitude velocity and longitude velocity. The position control of the UAV **20** position is independent of its yaw (heading), as the rotary winged aerial vehicle may hover and move in any direction. In addition to target pixel coordinates **560**, user commands **450** may also be received through the touch screen input interface **490** and may be converted by the command processor **530** into flight control commands **540**. Each of the desired velocity vector **600** and the flight control commands **540** may be sent to the UAV **20** over the communication network **30** (FIG. **1**) via the network interface **340**.

Target pixel coordinates **500** (FIG. **6**) differ from target pixel coordinates **560** in that the target pixel coordinates **500** are converted to a desired orientation **520** (FIG. **6**) that the UAV **20** should achieve, while target pixel coordinate **560** are converted to target world coordinates **580**.

The UAV state **420** is received from the UAV **20** over the communication network **30** (FIG. **1**) via the network interface **340**. The UAV position **440** is determined from the UAV state **420** by a position decoder **445**. The UAV state **420** is used to determine the orientation of the UAV **20**. The UAV position **440** is converted to UAV pixel coordinates **610** by a world coordinate to screen coordinate converter **620**. The UAV position **440** and the UAV pixel coordinates **610** may respectively determine the location and orientation of the UAV icon **110** on the map **60** of the first GUI (FIG. **2**), which is displayed on the touch-screen display interface **550**.

Navigation and Payload Processor

FIG. **8** is a schematic of high-level functional blocks of software components executing on the navigation and payload processor **220**, and flow of data between the software components, and between the software components and associated hardware. The UAV state **420** is received from the vehicle control unit processor **210** (FIG. **4**) via the CLI **290**. A data logger **630** records the UAV state **420** in a data storage **640**, preferably persistent data storage. This record of the

UAV state **420** may be sent through the onboard network interface **425**, preferably through the onboard WiFi™ adaptor **240**. Similarly, data from a payload interface **660**, which may include still photo, video, sound, enhanced imagery such as infrared or night vision, or other data, may be stored in data storage **640** and may be sent through the onboard network interface **425**, preferably through the onboard WiFI™ adaptor **240**. The UAV state **420** and data from the payload interface **660** may also be sent through the onboard network interface **425**, preferably through the onboard wireless modem **250**, without first being stored in the data storage **640**.

Navigation commands **410** may be received by the navigation and payload processor **220** through the onboard network interface **425** (FIG. **5**). Navigation commands **410**, preferably desired velocity **600**, desired orientation **520**, desired height **690**, and desired yaw **525** may be sent to the vehicle control unit processor **210** (FIG. **4**) via the CLI **290** without being processed by the navigation and payload processor **220**. Desired height **690** is preferably expressed as distance above ground level. Navigation commands **410**, preferably flight control commands **540**, are sent to a navigator **650**. The navigator **650** processes flight control commands **540** relating to waypoint navigation into a desired position **680**, preferably expressed as latitude, longitude, and heading. The desired position **680** is sent to the vehicle control unit processor **210** (FIG. **4**) via the CLI **290**.

Vehicle Control Unit Processor

FIG. **9** is a schematic of high-level functional blocks of software components executing on a vehicle control unit processor **210**, and flow of data between the software components, and between the software components and associated hardware.

The IMU sensors **260** may provide data to an orientation estimator **670**, which preferably estimates the roll, pitch, and yaw of the UAV **20** to provide an estimated orientation **790** (FIG. **10**) of the UAV **20**. Output data from the orientation estimator **670**, the onboard GPS receiver **270**, and a height estimator **535**, may be combined as the UAV state **420** and sent to the navigation and payload processor **220** (FIG. **4**) via the CLI **290**. The onboard GPS receiver **270** preferably provide the UAV position **440** and the speed of the UAV **20**. The height estimator preferably provides an estimated height **950** (FIG. **12**) of the UAV **20** above the ground, based on input from a sonar sensor **750** and a pressure sensor **760**. The pressure sensor **760** may measure absolute air pressure, while the sonar sensor **750** may detect the ground using conventional sonar. The sonar sensor **750** may operate for low-altitude flight (below approximately six meters), and may often be used for takeoff and landing.

The desired position **680**, desired velocity vector **600**, desired orientation **520**, and desired height **690** may be received from the payload processor **220** (FIG. **4**) via the CLI **290**. Each of these inputs may be processed by the vehicle control unit processor **210** to direct motors **700** of the UAV **20**. There are preferably four motors **700** on the UAV **20**, each preferably connected to a rotor.

A position controller **770** may determine the required orientation of the UAV **20**. To make this determination, the position controller **770** may require the UAV position **440** (FIG. **11**), the speed of the UAV **20**, a current wind speed and direction **900** (FIG. **11**), and either the desired position **680** or desired velocity vector **600**. The UAV position **440** and the speed of the UAV **20** may be provided by the onboard GPS receiver **270**. The wind estimator **780**, may estimate current wind speed and direction **900** by comparing a model-based prediction of the air-speed velocity to the ground velocity of the UAV **20** measured by the onboard GPS receiver **270**. The required orientation of the UAV **20** may then be sent to an orientation controller **740**. Alternatively, the desired orientation **520** may be sent directly to the orientation controller **740** from the navigation and payload processor **220** (FIG. **4**) via the CLI **290**.

The orientation controller **740** may determine desired differential control thrusts **930** (FIG. **11**) of the motors **700**. To make this determination, the orientation controller may require an estimated orientation **790** (FIG. **10**) of the UAV **20**, and either the desired orientation **520** or the required orientation of the UAV **20** as provided by the position controller **770**, or the desired yaw **525**. The desired differential control thrusts **930** (FIG. **11**) are sent to a motor controller **710**.

A height controller **730** may determine the required vertical thrust of the motors **700**. To make this determination, the height controller **730** may require the desired height **690**, the estimated height **950** (FIG. **12**), and the current and desired vertical velocities of the UAV **20**.

The motors **700** may be controlled by the motor controller **710**. The motor controller **710** may compute the motor speeds required to achieve the desired thrusts and maintains the motor speeds by comparing the required speeds to the measured speeds of the motors. The speed of the motors **700** may be measured by hall-effect sensors, voltage or current feedback of multi-phase electric motors, or other rotational speed measurement systems. A speed feedback **720** may include the measured speeds of the motors **700**. The motor controller **710** performs its computation based input from the speed feedback **720**, the desired thrust from the height controller **730**, and the desired rotational torques from the orientation controller **740**.

FIG. **10** is a flow chart of high-level functional blocks of software components executing on the UAV orientation estimator **670**. The orientation estimator **670** may use a Kalman Filter to update and correct the estimated orientation **790** by fusing body-frame accelerations **830**, body-frame angular rates **840**, and body-frame magnetic field strength **850**. The body-frame accelerations **830**, body-frame angular rates **840**, and body-frame magnetic field strength **850** may be measured by IMU sensors **260** (FIG. **9**).

FIG. **11** is a flow chart of high-level functional blocks of software components executing on the UAV position controller **770** and orientation controller **740**. A mode switch **860** may allow input in the form of either a desired position **680** or a desired velocity vector **600**. The desired position **680** input is sent to a NFZ boundary tester **890**. A velocity to position integrator **870** may transform the desired velocity vector **600** into the target position **875**, and the target position **875** may be sent to the NFZ boundary tester **890**. The NFZ boundary tester **890** combines NFZ and perimeter data **880** with either the desired position **680** or the target position **875** to determine whether any further movement of the UAV **20** toward the desired position **680** or target position **875** will cause the UAV **20** to enter a NFZ **160** or leave a perimeter **170** (FIG. **2**). The result produced by the NFZ boundary tester **890** may be summed with the UAV position **440**, then sent to a desired orientation calculator **910**. The desired orientation calculator **910** may combine the sum of the NFZ boundary tester **890** and UAV position **440** input with the current wind speed and direction **900**.

The desired orientation calculator **910** may send its output to a the world to control frame converter **920**, which converts the required UAV **20** orientation into the control coordinate frame **200** orientation by rotating the input orientation about the Z axis of the UAV **20**. The result of the conversion from global frame **180** into body frame **190** is combined with the estimated orientation **790** and the result is inputted to the orientation controller **740**, which uses a feedback control loop to compute desired differential control thrusts **930**. The desired differential control thrusts **930** may either maintain a course that directs the UAV **20** towards either the desired position **680** or target position **875**. Alternatively, if any further movement by the UAV **20** toward the desired position **680** or target position **875** will cause the UAV **20** to enter a NFZ **160** or leave a perimeter **170** (FIG. **2**), the UAV **20** may cease moving toward the desired position **680** or target position **875** and the desired orientation calculator **910** will automatically calculate an orientation that will cause the UAV **20** to maintain its current position.

FIG. **12** is a schematic of high-level functional blocks of software components executing on the UAV height controller **730**, and flow of data between the software components, and between the software components and associated hardware. The estimated height **950** of the UAV **20** may be determined by applying an algorithm which combines data from a sonar Kalman filter **970** and a pressure Kalman filter **980**. The sonar Kalman filter **970** may fuse data from a sonar sensor **750**, which provides a direct observation of height above ground with a maximum range of approximately 6 meters, and from accelerometers **990**. The pressure Kalman filter **980** may fuse data from a pressure sensor **760**, which estimates altitude of the UAV **20** based on air pressure, and from the accelerometers **990**. The output from the sonar Kalman filter **970** and the pressure Kalman filter **980** may be used by the height and altitude estimator **1000** to produce the estimated height **950**. The sum of the estimated height **950** and desired height **690** of the UAV **20** are sent to a height control system **960**, which determines the desired vertical thrust **940** to achieve the desired height **690**.

FIG. **13** is a flow chart of high-level functional blocks of software components executing on a UAV motor speed controller **710**. The UAV motor speed controller **710** calculates the speed of each motor **700** based on the required vertical thrust computed by the height controller **730**, and the differential thrusts computed by the orientation controller **740**. Thrusts from orientation **1010** are required to (FIG. **9**). Thrusts from height **1020** are required to achieve the desired height **690** (FIG. **9**). The thrusts from orientation **1010** and the thrusts from height **1020** are sent to a thrust mixer **1030**. The thrust mixer **1030** determines a set of thrusts that will achieve the desired orientation **520** or the required orientation as determined by the position controller **770**, and the desired height **690** (FIG. **9**), and which are within user-defined safe operating parameters. A motor speed calculator **1040** may map desired thrusts to corresponding motor speeds. The result obtained by the motor speed calculator **1040** may be combined with measured motor speeds **1050** and the result may be inputted to motor speed controller **710**, which may be a control system used to maintain desired motor speeds based on the differential between desired and measured speeds, and the motor voltage outputs **1070** may be generated.

Graphical User Interface (GUI)

FIG. **14** is a screenshot from a first GUI in a “press and hold” velocity input mode. The first GUI is divided into three broad sections: the map **60**, the payload window **70**, and the UAV status window **80**. The payload window **70** displays information obtained from the sensory payload, for example video feed **85** from the camera **230** (FIG. **4**). The UAV status window **80** displays information regarding status of various aspects of the UAV **20**, such as the status of network links, estimated accuracy of a position estimate provided by a GPS, and the amount of available data storage **640** (FIG. **8**).

The map **60** displays a representation of the environment in which the UAV **20** is operating. Information displayed on the map **60** includes a scale and compass **1080**, wind estimation and ground speed (magnitude and direction) **1090** of the UAV **20**, the UAV icon **110**, a current field of view **1100** of the camera **230**, and the straight-line path **120** between the current position UAV **20** as indicated by the UAV icon **110** and the target position **875** as indicated by the target position icon **130**. The target position **875** is determined by the desired velocity vector **600** (FIG. **11**). To create the desired velocity vector **600**, the user provides and maintains input through the touch-screen interface **360** at any point on the map **60**. The UAV **20** may begin to travel toward the target position **875** determined by the desired velocity vector **600**. The UAV **20** may reduce speed as it approaches the target position **875**, but will preferably continue to travel toward the target position **875** until it reaches the target position **875**. The UAV **20** will cease travelling toward the target position **875** if the user ceases to provide input defining the desired velocity vector **600**, or if the UAV **20** reaches the boundary of a NFZ **160** or perimeter **170**. If the UAV **20** ceases to travel toward the target position **875**, it may automatically adjust its desired differential control thrusts **930** (FIG. **11**), desired vertical thrust **940** (FIG. **12**), and motor voltage outputs **1070** (FIG. **13**).

This method of control allows the user to control the UAV **20** from an aerial reference frame as opposed to from the perspective of the UAV **20**. This method of control further allows the user to control the UAV **20** by providing a small number of high-level commands, rather than constantly providing inputs to the UAV **20**. In addition, if the UAV **20** is operating autonomously, inputs to the map **60** through the touch-screen interface **360** will not be directly passed to the UAV **20**, but may instead be integrated with the predefined mission profile in the form of a waypoint **1470** (FIG. **19**). Other commands such as ordering a UAV **20** to remain at its current position or activating sensor payloads can be made by providing user input through the touch-screen interface **360** at the mode icons **1220** (FIG. **15**) to create the corresponding flight commands **540**.

Flight commands **540**, navigation commands **410**, and other user commands **450** may be executed by providing user input through the touch-screen interface **360** at icons located on the map **60**. Input at a sensor icon **1120** may create targets **140** on the map **60** towards which the camera **230** (FIG. **4**) will pan if the target is selected. Input at a home icon **1130** may direct the UAV **20** to a pre-determined home location **150** on the map **60**. Input at a speed icon **1140** may toggle the UAV **20** between “high speed” and “low speed” modes, which impose different user-defined limits on the speed of the UAV **20**. Input at a pan icon **1150** may switches the map **60** into “pan” mode, which may allow the map to be dragged to view portions not centered on the UAV icon **110**. Input at a center icon **1060** may center the map **60** on the UAV **20**. Input at a takeoff icon **1170** may direct the UAV **20** to take off. Input at a land icon **1180** may directs the UAV **20** to land at its current position. The altitude slider **1012** displays and allows user control of the UAV **20**’s altitude. Status changes of the UAV **20**, such as motors starting, lifting off the ground, starting and stopping horizontal translation, and landing; and errors, such as sensor failures, wind estimates exceeding specified limits, and low battery conditions are indicated at the information bar **1190**.

FIG. **15** is a screenshot from a second GUI that may be used to implement the method in a “press and hold” velocity input mode. Important information relevant to the UAV **20** may be displayed in a floating panel **1200**. The floating panel **1200** may be proximate to the UAV icon **110**, allowing the user to determine the overall status of the UAV **20** at a glance and associate it with the location of the UAV **20**. Together, the

UAV icon **110**, the target position icon **130**, the target **140**, and the floating panel **1200** produce a terse recitation of relevant information pertaining to the system's capabilities across the operational area.

UAV choice icons **1210**, mode icons **1220**, and control icons **1230** are all used to provide input to the touch-screen interface **360** to create flight commands **540**, navigation commands **410**, and other user commands **450**. The user provides input through the UAV choice icons **1210** to chooses which UAV **20** to command from among a plurality of UAVs **20** (not shown). The UAV choice icons **1210** may change color to provide a convenient high-level indication of a the state of a given UAV. The user may provide input through the icons mode icons **1220** to work within one of five system operation modes: "operation", "mission edit", "mission review", "UAV configuration", and "UAV log". The user may provide input through the control icons **1230** to control the UAV **20** in one of four UAV control modes: "fully autonomous", "manually controlled", "emergency landing", and "base-return". Inputting any of these user commands **450** is simple and convenient requiring only one touch on the relevant portion of the touch-screen interface **360**. This may allow the user to control any given UAV **20** through any of the UAV control modes with only two actions. The first action is to choose which UAV **20** to control by inputting at one of the UAV choice icons **1210**, and then to choose the control mode to apply to that UAV **20** by inputting one of the control icons **1230** to create the relevant user command **450**.

The second GUI may consistently include an information bar **1190**. The other visible items may change depending on the current task, possibly including a top-down map **60** and map control icons **1240**, the video feed **85** and video feed control icons **1250**, and UAV status window **1260** (which differs from UAV status window **80**). Map control icons **1240** are analogous to the pan icon **1150** and center icon **1060**. An alternative embodiment of the invention may display the map **60** and map controls icons **1240**, the video feed **85** and control icons **1250**, and the UAV status window **1260** across different displays, either physical, for example an external display **50** or virtual. The icons **1265** are control-mode specific.

FIGS. **16**(*a*) and **16**(*b*) are screenshots from the second GUI illustrating changes in display that may occur upon changing the control mode of the UAV **20**. FIGS. **16** (*a*) and **16** (*b*) represent alternative configurations of the UAV status window **1260**. As the UAV **20** proceeds through a mission, users may require different information, and this status information is partially determined by the control mode being applied to a UAV **20**, as chosen by the user through inputting one of the control icons **1230**.

Changing between the respective configurations of the UAV status window **1260** shown in FIGS. **16** (*a*) and **16** (*b*) occurs automatically based on events such as user input through the control icons **1230** to choose a different UAV control mode. The user may also change the UAV status window **1260** without changing the UAV control mode by inputting on the touch-screen display **360** at one of the status display choice icons **1270** to create the relevant user command **450**. Some features are present on all configurations of the UAV status window **1260**, such as battery status display **1280**, while others are only present when the UAV is in a specific UAV control mode, such as UAV altitude display **1290**.

FIG. **17** is a screenshot from the first GUI in a "map-panning mode", which allows the user to pan the map **60**. This separates the UAV icon **110** from the center of the map **60**. The zoom level of the map **60** may be adjusted through slide bar **1295**.

FIG. **18** is a screenshot from the first GUI in a "mission edit" mode. In the "mission edit" mode, flight parameters may be adjusted. Flight parameters may include a perimeter **170** or a NFZ **160** (a first NFZ **1300** and a second NFZ **1310** are illustrated). The perimeter **170** is the area within which the UAV **20** may travel. The first NFZ **1300** is the area defined by four example of an NFZ point **1320**. The second NFZ **1310** is partially outside the perimeter **170**. NFZs are created through use of a point deletion icon **1330**, a point addition icon **1340**, and a NFZ deletion icon **1350**. The point deletion icon **1330** deletes the currently selected NFZ point from an NFZ. The point addition icon **1340** adds a new NFZ point **1320** and allows the user to edit an NFZ. The NFZ deletion icon **1350** removes the current NFZ completely. While the first NFZ **1300** and second NFZ **1310** are both quadrahedral, NFZs with any number of points greater than two may be created.

FIG. **19** is a screenshot from the second GUI in a "mission edit" mode. The NFZ icons **1360**, which are control-mode specific, are analogous to the point deletion icon **1330**, point addition icon **1340**, and NFZ deletion icon **1350** (FIG. **18**). The user may provide input through the mission edit icons **1370** to change the current feature being edited, or save and load missions. Features such as target position icons **130** and targets **140** may be removed from the GUI display to reduce clutter. A NFZ **160** is currently being edited, and other objects, for example the perimeter **170**, are rendered partially transparent to provide immediate visual indication of which features are being edited. The perimeter **170** in this instance is polygonal, in contrast to the perimeters **170** in FIGS. **2** and **18**, which are circular.

FIG. **20** is a screenshot from the first GUI being used to control the orientation of the UAV **20** directly through input of a desired orientation **520** (FIG. **6**). While operating the UAV **20** in this manner, input to the onboard GPS receiver **270** may be unnecessary. The following icons are available on the GUI and cause the corresponding persistent changes in orientation of the UAV **20**: trim UAV pitch (negative) icon **1380**, trim UAV roll (negative) icon **1390**, trim UAV roll (positive) icon **1400**, trim UAV pitch (positive) icon **1410**, manual UAV yaw control icon **1420**, manual UAV height control icon **1430**, land icon **1180**, takeoff icon **1170**, and user desired graphical velocity vector in the body frame (up equals forward) **1440**. A graphical velocity vector **1440** is shown with an origin **1450** and a head **1460**.

The simple and intuitive nature of the "press and hold" velocity input control method is further enhanced by the consistent behaviour and appearance of the first GUI and second GUI across the various possible tasks. The UAV choice icons **1210**, mode icons **1220**, and control icons **1230**, and the view commands **1240** remain constant regardless of the control mode being used. The control mode-specific map commands icons **1265** and **1360** differ as between the different UAV control modes, but are in the same location regardless of UAV control mode, and the map **60** incorporates common input methods through the touch-screen interface **360**, such as dragging to pan/move and tapping to select/add. The familiarity of users with the concept of dragging to pan, the same input to the portion of the payload window **70** displaying video feed **85** will pan the camera **230** accordingly.

This method of input is also extended to the manual control of the UAV **20**. While the UAV is being controlled in this fashion, navigation commands **410** can be created by inputting at the map **60** to input a desired velocity **600** or by inputting at the portion of the payload window **70** displaying video feed **85** to input a desired orientation **520**. When dragging in the portion of the payload window **70** displaying video feed **85**, the inputs should be transformed according to the orientation of the camera **230**. Manual control of the UAV **20** is more suitable for fine control of the selected UAV **20** than is creating a navigation command **410** by inputting at a given target pixel coordinates **560** on the map **60** displayed on the touch-screen interface **360**, but nonetheless maintains the method's intuitive and consistent input methods

FIGS. **14-20** illustrate that this control method for a UAV **20** may allow a variety of possible tasks including review of mission data, configuration and review of UAV **20** performance, design and modification of missions, execution of missions, automated control of a UAV **20** through navigation to waypoints, semi-automated control of a UAV **20** by choosing a desired destination **680**, manual control of a UAV **20**, review of data from the camera **230**, and control of the camera **230**. Furthermore, this control method for a UAV **20** allows all of these tasks to be efficiently and intuitively undertaken with a hardware platform as limited as a touch-screen.

Peripherals may be to the control station **10**. Peripherals may include an external display **50** or control device. One function of the external display **50** is to allow observation of sensor data from the payload of the UAV **20**, or of the GUI, on the external display **50**. Parties other than the user, and not in proximity to the user or to the UAV **20**, may also exercise direct control over the UAV **20** via direct control through a second control station **10**. This provides the opportunity for teamwork. For example output from the camera **230** may be controlled from a second control station **10** while the user, who may be physically closer to the UAV **20**, concentrates on navigating and editing missions for the UAV **20**. Potential control peripherals include off-the-shelf or custom input hardware such as gamepads, control stick, keyboards, trackballs, industrial steering devices, gesture recognition technology, speech recognition technology, or neural interfaces. No external displays **50** or control peripherals are required for the use of the system, but provide the possibility of increased operator efficiency at the cost of portability. When using a peripheral such as a gamepad or control stick, the flight of the UAV **20** may be controlled simultaneously with panning of the camera **230**. A control peripheral such as a gamepad or control stick may be used to generate a desired velocity vector **600** or a desired orientation **520**.

It will be understood that the systems and methods described herein may be embodied in a range of computing platforms, with the underlying hardware, operating system, and interface method varying. It should also be understood that various modifications can be made to the example embodiments described and illustrated herein, without departing from the general scope of the inventions and associated claims.

In the preceding description, for purposes of explanation, numerous details are set forth in order to provide a thorough understanding of the embodiments of the invention. However, it will be apparent to one skilled in the art that these specific details are not required in order to practice the invention. In other instances, well-known electrical structures and circuits are shown in block diagram form in order not to obscure the invention. For example, specific details are not provided as to whether the embodiments of the invention described herein are implemented as a software routine, hardware circuit, firmware, or a combination thereof.

Embodiments herein can be represented as a software product stored in a machine-readable medium (also referred to as a computer-readable medium, a processor-readable medium, or a computer usable medium having a computer-readable program code embodied therein). The machine-readable medium can be any suitable tangible medium, including magnetic, optical, or electrical storage medium including a diskette, compact disk read only memory (CD-ROM), memory device (volatile or non-volatile), or similar storage mechanism. The machine-readable medium can contain various sets of instructions, code sequences, configuration information, or other data, which, when executed, cause a processor to perform steps in a method according to an embodiment of the invention. Those of ordinary skill in the art will appreciate that other instructions and operations necessary to implement the described invention can also be stored on the machine-readable medium. Software running from the machine-readable medium can interface with circuitry to perform the described tasks.

The above-described embodiments are intended to be examples only. Alterations, modifications and variations can be effected to the particular embodiments by those of skill in the art without departing from the scope of the invention, which is defined solely by the claims appended hereto.

What is claimed is:

1. A method of remotely controlling a hovering unmanned aerial vehicle within an environment, the method comprising:

providing a control station in communication with the hovering unmanned aerial vehicle;

displaying, on a touch-screen interface at the control station, a visual representation of the environment;

receiving target pixel coordinates for the aerial vehicle on the touch-screen interface within the visual representation of the environment;

converting the target pixel coordinates into physical coordinates that are target world coordinates for the hovering unmanned aerial vehicle within the environment;

determining a desired vector to direct the hovering unmanned aerial vehicle based on the physical coordinates; and

based on the determined desired vector, directing the hovering unmanned aerial vehicle along the desired vector;

wherein the desired vector comprises a speed proportional to the distance between the hovering unmanned aerial vehicle and the target world coordinates.

2. The method of claim **1**, further comprising selecting a maximum speed which the hovering unmanned aerial vehicle will not exceed.

3. The method of claim **1**, further comprising directing the hovering unmanned aerial vehicle to take an action upon reaching the target world coordinates.

4. The method of claim **1**, further comprising controlling one or more functions of one or more of the hovering unmanned aerial vehicles by multiple control stations.

5. The method of claim **1**, wherein the user provides the target pixel coordinates by touching a target position icon on the visual representation of the environment.

6. The method of claim **1**, further comprising defining a flight parameter within the environment.

7. The method of claim **6**, wherein the flight parameter is selected from the group of a no-fly zone, a perimeter, a target, a home location, or a combination thereof.

8. The method of claim **6**, wherein the flight parameter is polygonal in shape.

9. The method of claim **1**, further comprising:

providing a sensory payload on the hovering unmanned aerial vehicle; and

transmitting data gathered by the sensory payload, directly or indirectly, to the control station.

10. The method of claim **9**, further comprising controlling the sensory payload independently of the hovering unmanned aerial vehicle.

11. The method of claim **1**, further comprising directing a plurality of hovering unmanned aerial vehicles from the control station.

12. The method of claim **1**, further comprising receiving an indication of a desired yaw for the hovering unmanned aerial vehicle independently of the received target pixel coordinates.

13. The method of claim **1**, wherein the desired vector is a velocity vector.

14. The method of claim **13**, wherein directing the hovering unmanned aerial vehicle comprises directing the hovering unmanned aerial vehicle along the determined desired velocity vector.

15. The method of claim **13**, further comprising recalculating the desired velocity vector as the hovering unmanned aerial vehicle travels towards the target world coordinates to reduce the speed of the hovering unmanned aerial vehicle as it approaches the target world coordinates.

16. The method of claim **13**, further comprising automatically directing the hovering unmanned aerial vehicle to remain at a current position if to continue travelling along the desired velocity vector would otherwise result in either directing the hovering unmanned aerial vehicle into a no-fly zone or directing the hovering unmanned aerial vehicle outside a perimeter.

17. The method of claim **13**, further comprising automatically directing the hovering unmanned aerial vehicle to remain at a current position prior to beginning to travel along the desired velocity vector if to travel along the desired velocity vector would at any point either direct the hovering unmanned aerial vehicle into a no-fly zone or direct the hovering unmanned aerial vehicle outside a perimeter.

18. A method of remotely controlling a hovering unmanned aerial vehicle within an environment, the method comprising:

providing a control station in communication with the hovering unmanned aerial vehicle;

displaying, on a touch-screen interface at the control station, a visual representation of the environment;

receiving target pixel coordinates for the aerial vehicle on the touch-screen interface within the visual representation of the environment;

converting the target pixel coordinates into physical coordinates for the hovering unmanned aerial vehicle within the environment;

determining a desired vector to direct the hovering unmanned aerial vehicle based on the physical coordinates; and

based on the determined desired vector, directing the hovering unmanned aerial vehicle along the desired vector;

wherein the user provides the target pixel coordinates by touching a target position icon on the visual representation of the environment and the hovering unmanned aerial vehicle remains at a current position if the user ceases to touch the target position icon.

19. A method of remotely controlling a hovering unmanned aerial vehicle within an environment, the method comprising:

providing a control station in communication with the hovering unmanned aerial vehicle;

displaying, on a touch-screen interface at the control station, a visual representation of the environment;

receiving target pixel coordinates for the aerial vehicle on the touch-screen interface within the visual representation of the environment;

converting the target pixel coordinates into physical coordinates for the hovering unmanned aerial vehicle within the environment;

determining a desired vector to direct the hovering unmanned aerial vehicle based on the physical coordinates;

based on the determined desired vector, directing the hovering unmanned aerial vehicle along the desired vector;

receiving an indication of a desired yaw for the hovering unmanned aerial vehicle; and

changing the yaw of the hovering unmanned aerial vehicle independently of the determination of the desired vector.

20. A method of remotely controlling a hovering unmanned aerial vehicle within an environment, the method comprising:

providing a control station in communication with the hovering unmanned aerial vehicle;

displaying, on a touch-screen interface at the control station, a visual representation of the environment;

receiving target pixel coordinates for the aerial vehicle on the touch-screen interface within the visual representation of the environment;

converting the target pixel coordinates into physical coordinates for the hovering unmanned aerial vehicle within the environment;

determining a desired vector to direct the hovering unmanned aerial vehicle based on the physical coordinates; and

based on the determined desired vector, directing the hovering unmanned aerial vehicle along the desired vector;

wherein the desired vector is an orientation vector.

21. The method of claim **20**, wherein receiving the target pixel coordinates comprises receiving a continuous indication of target pixel coordinates.

22. The method of claim **21**, wherein directing the hovering unmanned aerial vehicle comprises directing the hovering unmanned aerial vehicle until the continuous indication of target pixel coordinates is no longer being received.

23. The method of claim **20**, wherein the orientation vector comprises roll, pitch, or both roll and pitch.

24. A system for remotely controlling a hovering unmanned aerial vehicle within a physical environment, the system comprising:

at least one hovering unmanned aerial vehicle within a physical environment, the at least one hovering unmanned aerial vehicle comprising a plurality of independently driven rotors each rotor being mounted at a distance from a center of the at least one hovering unmanned aerial vehicle and each rotor associated with a rotor motor;

a control station in communication with a hovering unmanned aerial vehicle, the control station comprising a touch-screen interface; and

a processing system connected to the control station and configured to

send a signal to the control station to display, on the touch-screen interface, a visual representation of the environment and the hovering unmanned aerial vehicle;

receive target pixel coordinates within the visual representation of the environment for the hovering unmanned aerial vehicle from the touch-screen interface;

convert the target pixel coordinates into physical coordinates for the hovering unmanned aerial vehicle within the physical environment;

determine a desired vector to direct the hovering unmanned aerial vehicle within the physical environment based on the physical coordinates; and

based on the determined desired vector, send a signal to the rotor motors of the hovering unmanned aerial vehicle to direct the hovering unmanned aerial vehicle along the desired vector.

25. The system of claim **24**, wherein:

the processing system comprises a control unit within at least one hovering unmanned aerial vehicle and a control unit within the control station.

26. The system of claim **24**, wherein the at least one hovering unmanned aerial vehicle comprises one or more sensors and the processing system is configured to receive data from the one or more sensors.

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