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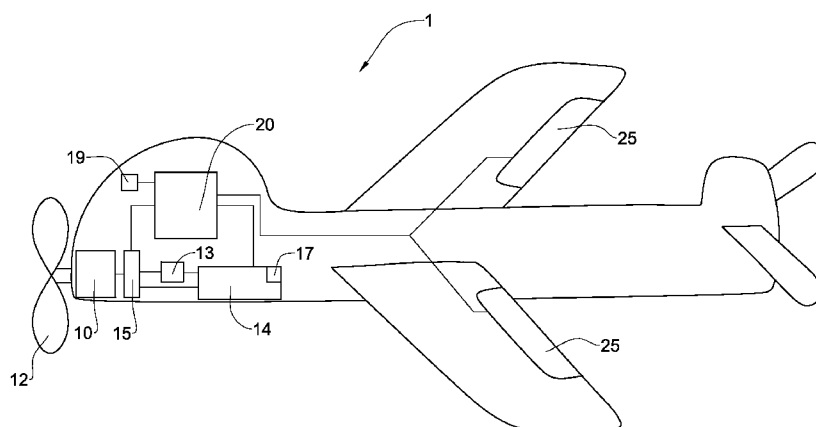


Fig. 2

(57) Abstract: An unmanned aerial vehicle having a task to be fulfilled, the unmanned aerial vehicle comprising: a rechargeable energy storage unit; a propulsion arrangement configured to operate in at least two operative modes; a direction control arrangement configured to control movement direction of the unmanned aerial vehicle; and a data processing unit in communication with the propulsion and energy generation arrangements and with said direction control arrangement. The data processing unit is configured to perform energy management of the unmanned aerial vehicle based on comparison of actual route parameters related to a real-time state of the unmanned aerial vehicle, with target route parameters including data related to target energy level in said energy storage unit.

AN UNMANNED AERIAL VEHICLE

FIELD OF THE DISCLOSED SUBJECT MATTER

The disclosed subject matter concerns unmanned aerial vehicles. In particular, it refers to unmanned aerial vehicles with efficient energy consumption.

BACKGROUND OF THE DISCLOSED SUBJECT MATTER

An unmanned aerial vehicle (UAV) is an aircraft without a human pilot onboard. UAVs can be remote controlled aircraft (e.g. flown by a pilot at a ground control station) or can fly autonomously based on pre-programmed flight plans or more complex dynamic automation systems. UAVs are currently used for a number of missions, including reconnaissance and attack roles. Their largest use is within military applications. UAVs are also used in a small but growing number of civil applications, such as firefighting or nonmilitary security work.

The UAVs can be operated by different sources of energy. One of these sources can be an electric source in which a rechargeable battery can be used for regenerating a potential energy of a UAV into an electric energy. One example of an electrically driven UAV is disclosed in US 2008/0184906. This reference discloses a hybrid UAV which is driven by a fuel-based source of energy and a regenerated electric energy which is storable in a rechargeable battery. This UAV is configured to charge the battery only during gliding thereof, in which the propeller of the UAV becomes a windmill, and it drives the electric motor/generator, so as to recharge the UAV's battery. This reference is an example to a UAV in which a potential energy of the UAV is converted to an electric energy.

SUMMARY OF THE DISCLOSED SUBJECT MATTER

The presently disclosed subject matter, in accordance with one aspect, provides unmanned aerial vehicle (UAV) having a task to be fulfilled. The UAV comprises:

- a. a rechargeable energy storage unit;
- b. a propulsion arrangement configured to operate in at least two operative modes:
 - a propulsion mode in which the propulsion arrangement is configured to use

- energy from at least the energy storage unit for driving the unmanned UAV; and an idle mode in which the propulsion arrangement is inoperative;
- c. an energy generation arrangement configured to operate in at least two operative modes: an energy generation mode in which the energy generation arrangement is configured to convert kinetic energy of streams of air in the surrounding of the UAV, into another form of a collected energy, and store at least a part of the collected energy in the energy storage unit; and an idle mode in which the energy generation arrangement is inoperative;
 - d. a direction control arrangement configured to control movement direction of the UAV; and
 - e. a data processing unit in communication with the propulsion and energy generation arrangements and with the direction control arrangement. The data processing unit is configured to perform energy management of the unmanned aerial vehicle based on comparison of actual route parameters related to a real-time state of the UAV, with target route parameters including data related to target energy level in the energy storage unit, by: determining, in view said target route parameters, selected operative modes and selected movement direction based on said comparison; and controlling navigation of the unmanned aerial vehicle at least by instructing the propulsion and energy generation arrangements to operate in the selected operative modes and instructing the direction control arrangement to control the unmanned aerial vehicle to move in the selected movement direction.

The idle mode of the propulsion arrangement, in which the propulsion arrangement is inoperative, can interpreted as a state in which the propulsion arrangement does not use energy from the energy storage unit for driving the UAV.

The idle mode of the energy generation arrangement, in which the energy generation arrangement is inoperative, can interpreted as a state in which the energy generation arrangement does not collect energy in the energy storage unit.

The another form of energy which is collected by the energy storage unit can be an electric energy.

The propulsion and energy generation arrangements can comprise a common electric motor-generator with a common propeller rotatably connected thereto, and the energy storage unit can be a rechargeable electric battery in which the electric energy is stored.

When the propulsion arrangement is in its propulsion mode, the energy storage unit supplies the electric energy to the electric motor-generator for rotating the propeller and thereby driving the UAV, and the energy generation arrangement is in its idle mode in which electric energy is not generated by the electric motor-generator and not stored in the energy storage unit.

When the energy generation arrangement is in its energy generation mode, the propeller is rotated by the streams of air in the surrounding of the UAV for converting the kinetic energy thereof into the electric energy via the electric motor-generator and storing the electric energy in the energy storage unit, and the propulsion arrangement is in its idle mode in which electric energy is not supplied from the energy storage unit to the electric motor-generator for rotating the propeller to drive the UAV.

By following the target route parameters, the UAV of the presently disclosed subject matter can be operated for efficiently generating and using an electric energy during the performance of a task (not only during gliding of the UAV).

The UAV of the presently disclosed subject matter is configured to convert kinetic energy of streams of air in its surrounding into an electric energy (e.g., by using its propeller as a windmill), to store the electric energy in an energy storage unit (e.g., a battery), and to use the collected electric energy for supplying all the power needed for performing the UAV's task. By being navigated and controlled in an efficient manner so as not to waste electric energy and to generate as much electric energy as possible, the UAV can preserve a possible energy balance within its energy storage unit, which allows it to be operated without using any additional sources of power, such as fuel. This efficient navigation of the UAV is based on the fact the kinetic energy of streams of air at the UAV's surrounding can be exploited for generating an electric energy by the energy generation arrangement during the whole task that the UAV performs (and not only during gliding thereof). For example, when the UAV is located in an upstream which causes it to gain altitude too fast while the propulsion arrangement is in the propulsion mode, the kinetic energy of the upstream can be exploited by the UAV's energy generation arrangement for generating an electric energy. This can be done, for example, by altering power supply the UAV's motor-generator so as to cause the propulsion arrangement to operate in its idle mode, and in turn by causing the energy generation arrangement to operate in the energy generation mode so as to generate electric energy by allowing the propeller to rotate as a windmill. Alternatively, this can be done by causing the energy generation

arrangement to operate in its idle mode, so as to cause the UAV the gain altitude (i.e., potential energy), which later can be used during gliding of the UAV for generating electric energy by the energy generation arrangement. Another way of managing the energy consumption in an efficient manner can be provided by directing to UAV from one to another location, so as to prevent waste of electric energy. This navigation can be performed by instructing the direction control arrangement accordingly.

In general, in order to generate an electric energy, the UAV can be directed to areas in which there are upstreams, and in order to prevent loss of potential energy thereof, the UAV can be prevented from passing in downstreams.

The UAV can include a plurality of propulsion arrangements which can operate simultaneously to each other, or independently from each other.

The UAV can include a plurality of energy generation arrangements which can operate simultaneously to each other, or independently from each other.

The UAV can further include at least one external energy generation arrangement configured to operate in at least two operative modes: an energy generation mode in which said energy generation arrangement is configured to convert energy from sources of energy being different from streams of air in the surrounding of the unmanned aerial vehicle (e.g., a solar energy), into another form of generated energy (e.g., an electric energy), and store at least a part of said generated energy in the energy storage unit; and an idle mode in which the external energy generation arrangement is inoperative. The data processing unit is further configured to perform energy management by selecting the operative mode of the external energy generation arrangement and by instructing the external energy generation arrangement to operate in the selected operative mode, accordingly.

The external energy generation arrangement can work in conjunction with the above defined energy generation arrangement of the UAV for charging the energy storage unit. This operation can be performed by the data processing unit which performs optimization of the energy sources from which the energy will be collected, so as to generate an electric energy in an efficient manner.

The term '**speed vector**' refers hereinafter to a vector of speed which can represent a physical measure of speed in one, two or three dimensions. The speed vector can represent a ground or an aerial speed of the UAV.

The term '**geographic position**' refers to a geographic position of an aerial vehicle, which can include the altitude of the aerial position above the sea or the ground.

The term '**downstream**' refers hereinafter to a stream of air which is directed towards the earth, and the term '**upstream**' refers hereinafter to a stream of air which is directed against the direction of earth.

The actual route parameters can include: a task timetable, an actual speed vector, an actual energy level, and an actual geographic position.

The target route parameters can include a plurality of task location parameters, each related to a target location and being characterized by sub-parameters including: a target speed vector range; a target energy range related to the target energy level; and a target geographic position.

In order to know how and in which modes the propulsion arrangement, the energy generation arrangement and the direction control arrangement should be operated, the UAV's data processing unit constantly receives information related to the task timetable, the speed of the UAV (the actual speed vector), the level of electric energy in the UAV's battery (the actual energy level) and the UAV's geographic position (the actual geographic position). After analyzing these parameters by comparing them with the target route parameters, the data processing unit instructs the propulsion and energy generation arrangements to operate in accordingly selected operative modes and the direction control arrangement to control the UAV to move in a selected movement direction. By performing this control, the UAV is navigated to perform its task with efficient electric energy consumption and management.

The UAV can further comprise the following elements:

- a. a geographical position measuring arrangement, in communication with the data processing unit, configured for providing the actual geographic position;
- b. a speed measuring arrangement, in communication with the data processing unit, configured for providing the actual speed vector of the unmanned aerial vehicle; and
- c. at least one energy level measuring arrangement, in communication with the data processing unit, configured for measuring the actual energy level in the energy storage unit.

The actual speed vector can be calculated by the speed measuring arrangement according to variation in time of the actual geographic position.

The data processing unit can be configured for performing the comparison by calculating comparison parameters by comparing: the actual geographic position with the target geographic position of a closest target location, the actual speed vector with the target speed vector range of the closest target location, and the actual energy level with the target energy range of the closest target location

The data processing unit can further be configured for selecting the selected operative modes of the propulsion and energy generation arrangements and the selected movement direction of the UAV by performing optimization of the comparison parameters.

The data processing unit can further be configured to perform the comparison and the selection of the selected operative modes in a repetitive manner upon variation of the actual geographic position.

The target geographic position of each of the task location parameters can be calculated according to the task timetable and a map of airstreams which includes upstreams and downstreams.

Each of the plurality of task location parameters can be further characterized by a speed vector threshold, an energy threshold, and a distance threshold, so that when at least one of the comparison parameters is inconsistent with at least one of: the speed vector threshold, the energy threshold, and the distance threshold, the data processing unit will recalculate at least one of the target location parameters.

The instruction of the propulsion arrangement by the data processing unit can further include a step of controlling power supply to the motor-generator.

The actual speed vector can be characterized by an actual speed vector direction and size, and the target speed vector range includes a plurality of target speed vectors, each having a target speed vector direction and size. The comparison can be performed by selecting a preferred target speed vector of the target speed vectors and comparing the actual speed vector direction and size with the target speed vector direction and size of the preferred target speed vector.

According to a specific example, when the following conditions are fulfilled:

- a. the actual speed vector direction equals to the target speed vector direction of the preferred target speed vector;
- b. the actual speed vector size is larger than the target speed vector size of the preferred target speed vector;
- c. the actual energy level is below or within the target energy range;

- d. the propulsion arrangement is in its propulsion mode; and
- e. the energy generation arrangement is in its idle mode;
the data processing unit can be configured to perform one of:
 - (i) reducing power supply to the propulsion arrangement; and
 - (ii) selecting the idle mode of the propulsion arrangement and the energy generation mode of the energy generation arrangement, and instructing the propulsion and energy arrangements accordingly.

According to another specific example, when the following conditions are fulfilled:

- a. the actual speed vector direction equals to the target speed vector direction of the preferred target speed vector;
- b. the actual energy level is within or above the target energy range;
- c. the actual speed vector size is smaller than the target speed vector size of the preferred target speed vector;
- d. the propulsion arrangement is in its idle mode; and
- e. the energy generation arrangement is in its generation mode;
the data processing unit can be configured to perform any one of:
 - (i) increasing power supply to the propulsion arrangement; and
 - (ii) selecting the idle mode of the energy generation arrangement and the propulsion mode of the propulsion arrangement.

The presently disclosed subject matter, in accordance with one aspect, provides a method for operating an unmanned aerial vehicle having a task to be fulfilled. The method comprises steps of:

- a. providing an unmanned aerial vehicle comprising: a rechargeable energy storage unit; a propulsion arrangement; an energy generation arrangement; a direction control arrangement; and a data processing unit in communication with the propulsion and energy generation arrangements and with the direction control arrangement;
- b. operating said propulsion arrangement in at least two operative modes: a propulsion mode in which said propulsion arrangement is configured to use energy from at least said energy storage unit for driving said unmanned aerial vehicle; and an idle mode in which said propulsion arrangement is inoperative;
- c. operating said energy generation arrangement in at least two operative modes: an energy generation mode in which said energy generation arrangement is

- configured to convert kinetic energy of streams of air in the surrounding of said unmanned aerial vehicle, into another form of a collected energy, and store at least a part of the collected energy in the energy storage unit; and an idle mode in which said energy generation arrangement is inoperative;
- d. controlling movement direction of the unmanned aerial vehicle at an actual location thereof by the direction control arrangement; and
 - e. operating said data processing unit for performing energy management of the unmanned aerial vehicle based on comparison of actual route parameters related to a real-time state of the unmanned aerial vehicle, with target route parameters including data related to target energy level in said energy storage unit, by steps of:
 - (i) determining, in view said target route parameters, selected operative modes and selected movement direction based on said comparison; and
 - (ii) controlling navigation of said unmanned aerial vehicle at least by instructing said propulsion and energy generation arrangements to operate in the selected operative modes and instructing said direction control arrangement to control the unmanned aerial vehicle to move in the selected movement direction.

By using the method of the presently disclosed subject matter, the UAV can be in the air for a very long time, and in optimal conditions in which there, for example, enough upstreams, the UAV can be in the air for unlimited periods of time.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the disclosed subject matter and to see how it may be carried out in practice, embodiments will now be described, by way of non-limiting examples only, with reference to the accompanying drawings, in which:

Fig. 1A is a schematic perspective three dimensional view of an exemplary task map in which the UAV can be navigated for fulfilling a predetermined task;

Fig. 1B is a schematic perspective two dimensional upper view of an exemplary task map in which the UAV can be navigated for fulfilling a predetermined task;

Fig. 2 is a schematic detailed illustration of the UAV of Figs. 1A and 1B in which the main elements of the UAV are presented according to one example; and

Fig. 3 is a schematic illustration of a method according to which the UAV of the presently disclosed subject matter can be operated.

DETAILED DESCRIPTION OF EMBODIMENTS

According to one example of the presently disclosed subject matter, the presently disclosed subject matter is directed to an unmanned aerial vehicle (UAV) having a task to be fulfilled, which is configured to exploit kinetic energy of streams of air in its surrounding for generating an electric energy, to store it within an energy storage unit (e.g., an electric battery), and to use the electric energy for supplying all the power needed for performing the task.

In order to fulfill the task, the UAV has to be navigated and controlled in an efficient manner so as to preserve a positive energy balance which would allow it to have enough electric energy during the performance of the task. This navigation and control, by which the UAV can be operated without using any additional sources of power (such as fuel), involves preventing unwanted waste of electric energy and collecting as much electric energy as possible. By this efficient navigation and control, the UAV can for example be directed to areas in which there are upstreams, for example, for collecting an electric energy, and the UAV can be directed so as to avoid areas in which there are downstreams, for example, for preventing waste of electric energy. This operation of the UAV is detailed below.

Reference is now made to Figs. 1A and 1B, which schematically illustrate a perspective three dimensional view and an upper two dimensional view, respectively, of an exemplary task map 40, in which an UAV 1 can be navigated for fulfilling a predetermined task according to a task timetable, by being operated only by an electric energy which is generated and exploited by the UAV 1 during the performance of the task, and stored in a rechargeable energy storage unit of the UAV 1, in form of a rechargeable battery 14 (shown in Fig. 2). The task map 40 includes a target route 30 (represented in Figs. 1A and 1B by a broken line) defined by a plurality of target locations 32 at which or in proximity to which the UAV 1 should fly during the performance of the task.

In general, a task of the UAV 1 is defined by a plurality of target route parameters. The target route parameters, which can be calculated according to various optimization techniques, are guiding parameters according to which the UAV 1 should be navigated and operated for preserving a predetermined level of electric

energy (i.e., target energy level) in the battery 14 during the performance of the task. In order to fulfill the task with enough electric energy in the energy storage unit, the UAV 1 has to comply with and being controlled and navigated according to the target route parameters that include data related to target energy level in the energy storage unit. The target energy level is the desired level of electric energy which should be stored in the battery 14 during the performance of the task. By performing real-time assessment of actual route parameters that are related to a real-time state of the UAV 1, and comparing the actual route parameters with the target route parameters, the task can be fulfilled as planned.

The target route parameters include a plurality of task location parameters, each related to each of the target locations 32. Each of the task location parameters is characterized by the following sub-parameters: a target speed vector range; a target energy range related to the target energy level; and a target geographic position. The target speed vector range which is related to a specific target location 32, defines a range of speeds in which the UAV should fly at the target location or in proximity thereto. The target energy range expresses the level of electric energy that should be stored in a UAV's battery 14 when the UAV flies at the target location or in proximity thereto.

According to one example, the actual route parameters include the following parameters: a task timetable, an actual speed vector, an actual energy level, and an actual geographic position. The task timetable is the timetable according to which the UAV's task has to be performed. The actual speed vector of the UAV is the real-time measured vector of the UAV's speed. The actual energy level is the real-time level of electric energy in the UAV's energy storage unit. The actual geographic position is the real-time estimated geographic position of the UAV.

The task map 40 which is shown in Figs. 1A and 1B includes exemplary illustrations of upstream locations U1 and U2, downstream locations D1 and D2, and an operation zone Z1. The task location parameters are calculated according to the geographic position of the upstream locations U1 and U2 and the downstream locations D1 and D2 which are used for lifting and lowering the UAV, respectively, and according to various considerations related to the task and to the energy consumption and accumulation by the UAV 1. For example, the target geographic position of each of the task location parameters 32 can be calculated according to the task timetable of the UAV 1 and a map of known locations of upstreams and

downstreams. The identification of the locations in which there are upstreams and downstreams is known in the art, and can be obtained, for example, from real-time weather conditions of weather forecasts and can be dependent on the time of the day at which the task is performed.

The operation zone Z1 is the geographical area to which the UAV should arrive with enough electric energy needed for performing there an operation (e.g., photographing), as part of its task. By performing the real-time assessment of the actual route parameters and flying according to the task location parameters, the UAV 1 is able to preserve a positive energy balance which is important for allowing it to have enough electric energy for arriving to the operation zone Z1 and staying there enough time for performing there a specific operation as part of its task. Whilst the positive energy balance is preserved, the UAV can stay in the air, as much time as needed. This period of time can be very long, and can last for days or months, if required.

Reference is now made to Fig. 2, which schematically illustrates one example of the UAV 1 with the following main elements involved in the energy management: a data processing unit 20; the battery 14; a propulsion and an energy generation arrangements which share a common switch 15 and a common electric motor-generator 10 with a propeller 12 rotatably connected thereto; an AC/DC convertor 13 which is part of the energy generation arrangement; and a direction control arrangement 25 configured to control movement direction of the UAV 1. According to other examples, the battery 14 can be additionally externally charged by other techniques such as from a power grid.

The energy generation arrangement of the UAV 1 is configured to operate in two operative modes: an energy generation mode and an idle mode. In the energy generation mode, the energy generation arrangement converts the kinetic energy of streams of air at the UAV's surrounding to an electric energy, and stores the collected electric energy in the battery 14. In this mode of operation of the energy generation arrangement, the propeller 12 is rotated by the streams of air at the UAV's surrounding by allowing the propeller 12 to become a windmill. This rotation of the propeller 12 causes the motor-generator 10, which is used as a generator, to generate an electric energy which is thereafter converted by the AC/DC convertor 13 to a DC power. This DC power is later stored in the battery 14. In the idle mode of the energy generation arrangement, the energy generation arrangement is inoperative, i.e., the

energy generation arrangement does not generate an electric energy to be store in the battery 14.

The propulsion arrangement of the UAV 1 is configured to operate in two operative modes: a propulsion mode and an idle mode. The propulsion arrangement of the UAV 1 is responsible for driving the UAV 1 by using an electric energy from the battery 14. In the propulsion mode, the propulsion arrangement uses electric energy stored in the battery 14 for propelling the UAV 1 by rotating the propeller 12 via the motor-generator 10, which is used as a motor in this case. In the idle mode of the propulsion arrangement, the propulsion arrangement is inoperative, i.e., an electric energy is not supplied to the motor-generator 10 from the battery 14 for rotating the propeller 12 and thereby driving the UAV 1.

Due to the fact that the propulsion and energy generation arrangements of the example presented in Fig. 2 share common elements, such as the propeller 12 and the motor-generator 10, when the propulsion arrangement is in its propulsion mode, the energy generation arrangement is in its idle mode, and when the energy generation arrangement is in its energy generation mode, the propulsion arrangement is in its idle mode. In other words, according to the present example, when the propulsion arrangement is in its propulsion mode and the energy generation arrangement is in its idle mode, the propeller 12 uses the electric energy stored in the battery 14 for rotating the motor-generator 10 for driving the UAV 1 and causing it to fly. On the other hand, when the propulsion arrangement is in its idle mode, and the energy generation arrangement is in its energy generation mode, the propeller 12 is rotated by the streams of air, at the same direction as during propelling of the UAV by the propulsion arrangement, for converting kinetic energy into an electric energy by the motor-generator 10, that is being used as a generator.

As shown in Fig. 2, the data processing unit 20 is electrically connected to the switch 15 for regulating the operation modes of the propulsion and the energy generation arrangements.

As already mentioned above, the operation of the UAV 1 is based on the fact the streams of air at the UAV's surrounding can be exploited for collecting an electric energy when available, during the whole task that the UAV performs (and not only during decent thereof). For example, when the UAV 1 is located in an upstream which causes it to gain altitude too fast while the propulsion arrangement is in the propulsion mode, the extra power of the upstream can be exploited for generating an electric

energy by the UAV's energy generation arrangement. This can be done, for example, by altering power supply the UAV's motor-generator 10 so as to cause the propulsion arrangement to operate in the idle mode, and in turn by causing the energy generation arrangement to operate in the energy generation mode so as to generate electric energy for the propeller 12 which continues to rotate (by the power of the streams of air).

Another way of managing the energy consumption in an efficient manner can be provided by directing to UAV from one to another location, so as to prevent waste of electric energy. This can be performed by the direction control arrangement 25.

This navigation of the UAV 1 according to the target route parameters is performed by the data processing unit 20 which obtains the target route parameters and the actual route parameters, perform various calculations, controls the operation of the UAV's propulsion and energy generation arrangements in one of their mode of operation (detailed below) and controls movement direction of the UAV 1 via the direction control arrangement 25. The operation of the data processing unit 20 by performing assessment of the actual route parameters so as to comply with the target route parameters, allows the UAV 1 to perform real-time energy management in order to fulfill the UAV's task as planned, and with self-generated electric energy supply.

In order to know how and in which modes the propulsion arrangement, the energy generation arrangement and the direction control arrangement should be operated for complying with the target route parameters, the data processing unit 20 performs energy management based on comparison of actual route parameters with target route parameters. For this comparison, the data processing unit 20 constantly receives information related to the task timetable, the speed of the UAV (actual speed vector), the level of electric energy in the UAV's battery 14 (actual energy level) and the UAV's geographic position (actual geographic position), and analyses this data as detailed below. After analyzing these parameters, and comparing them with the target route parameters, the data processing unit 20 selects and determines the operative modes of the propulsion and energy generation arrangements and the movement direction of the direction control arrangement. Following this, the data processing unit 20 controls the navigation of the UAV 1 by instructing the propulsion and energy generation arrangements to operate in the selected operative modes and the direction control arrangement to control the UAV 1 to move in the selected movement direction. By performing this control, the UAV 1 is navigated to perform its task with

efficient electric energy consumption and management in which a positive energy balance can be preserved for allowing the UAV to stay in the air as much time as needed (e.g., for days or months).

The data processing unit 20 includes a processor (not shown) and a data storage unit (not shown). The data storage unit receives and stores the target route parameters, and the actual route parameters, and the processor performs all the calculations of data processing unit 20.

By controlling the navigation of the UAV 1 so that it will fly along to the target route 30 (i.e., by passing in proximity to the target geographic positions of the target locations 32) and according to other target route parameters, an optimal exploitation of the kinetic energy of the streams of air can be achieved for collecting as much electric energy as needed for fulfilling the UAV's task. This optimal exploitation of the kinetic energy of the streams of air by the includes, the following examples according to which the UAV 1 can navigated:

- rising UAV's flight altitude in upstreams so as to collect potential energy. This potential energy is later converted to an electric energy during gliding of the UAV by free rotation of the propeller 12, and respective energy generation by the UAV's energy generation arrangement which is operated during the gliding in its energy generation mode, while the propulsion arrangement is operated in its idle mode;
- exploiting the upstreams by letting them to rotate the propeller 12 as a windmill, while the energy generation arrangement is in its energy generation mode for collecting an electric energy due to rotation of the propeller 12, and the propulsion arrangement is in its idle mode;
- eliminating downstreams for preventing loss of potential energy and/or kinetic energy of the propeller 12 during rotation thereof;
- exploiting downstreams by navigating the UAV thereto for reaching the operation zone Z1 (or another geographic location) as fast as possible;
- exploiting downstreams by navigating the UAV thereto for shortening and/or terminating the task as fast as possible.

For example, by planning the target route 30 so that it will pass in upstream locations, such as the upstream locations U1 and U2, the energy generation arrangement can be operated in its energy generation mode so as to cause the streams of air at the UAV's surrounding to rotate the propeller 12. This rotation of the

propeller 12 will cause generation of electric energy by the motor-generator 10 connected thereto and storage of the electric energy in the UAV's battery 14. Alternatively, the streams of air at the upstream locations can allow the UAV to gain altitude during operation of the energy generation and the propulsion arrangements in their idle modes. As mentioned above, the gained altitude is a potential energy that can be transformed to kinetic energy of the propeller 12. This transformation of the potential energy to the kinetic energy of the propeller 12 is provided by the streams of air which rotate the propeller 12 during gliding of the UAV 1. This kinetic energy is afterwards converted to electric energy as explained above.

The UAV 1 further comprises a geographical position measuring arrangement 19 (e.g., a GPS arrangement) which is in communication with the data processing unit 20. The geographical position measuring arrangement 19 is configured to estimate and provide the actual geographic position of the UAV 1. According to the example of Fig. 2, the geographical position measuring arrangement 19 is used also as a speed measuring arrangement configured to provide an actual speed vector of the UAV 1. The actual speed vector is a real-time speed vector of the UAV at the actual geographic position of the UAV in the three-dimensional space in which the UAV flies. The actual speed vector is characterized by an actual speed vector direction and an actual speed vector size. The data processing unit 20 is connected to the speed vector measuring arrangement 19 for receiving data related to the actual geographic position and the actual speed vector of the UAV 1.

The UAV 1 further comprises an energy level measuring arrangement 17, in communication with the data processing unit 20, configured for measuring an actual energy level in the battery 14. The actual energy level is the real-time percentage of the battery's 14 charge, the value of which can be between 0% (i.e., an empty battery) and 100% (i.e., a fully charged battery). The data processing unit 20 is connected to the battery 14 for receiving power supply and it is connected to the energy level measuring arrangement 17 for receiving data related to the actual energy level in the battery 14.

Reference is now made to Fig. 3, which schematically illustrates steps of a method 200 according to which the energy management of UAV 1 is performed, and particularly, the steps according to which the data processing unit 20 performs energy management of the UAV 1.

In step 110, the data processing unit 20 obtains and/or updates the actual route parameters and the target route parameters. The actual route parameters are updated in real-time during the performance of the task. For example, the actual geographic position is estimated by the geographical position measuring arrangement 19, the actual speed vector is estimated by the speed measuring arrangement (according to the present example, the geographical position measuring arrangement 19), and the actual energy level is estimated by the energy level measuring arrangement 17. These actual route parameters are updated repeatedly during the performance of the task at a predetermined rate, and/or upon change of the actual geographic position. For example, the actual speed vector is calculated by the speed measuring arrangement according to variation in time of the actual geographic position which is measured by the geographical position measuring arrangement 19.

The target route parameters, and particularly the task location parameters can be received from an external source of information such as a main controlling center, or other UAVs. The target route parameters can also be calculated by the data processing unit 20 itself according to other parameters related thereto.

In step 120, the data processing unit 20 compares the task location parameters with the actual route parameters, and calculates corresponding comparison parameters which are related to the results of this comparison. In order to perform the comparison, the data processing unit 20 selects a task location 32, which can be the closest task location of the UAV during its course of flight. As part of this comparison, the following parameters are compared: the actual geographic position is compared with the target geographic position of the closest task location parameter, the actual speed vector is compared with the target speed vector range of the closest task location parameter, and the actual energy level is compared with the target energy range of the closest task location parameter. The data processing unit 20 can use different known calculation techniques for performing the comparison.

The actual speed vector is characterized by an actual speed vector direction and size, and the target speed vector range includes a plurality of target speed vectors, each having a target speed vector direction and size. As part of step 120, in which the comparison parameters are calculated, a preferred target speed vector is selected of the target speed vectors, and the actual speed vector direction and size is compared with the target speed vector direction and size of the preferred target speed vector.

Due to the fact that in real-life conditions there are various reasons and factors which can cause the UAV 1 not to comply with the target route parameters, these parameters, and particularly the task locations, can be periodically recalculated in order to perform the task successfully. This recalculation is performed as follows: Each of the task location parameters is further characterized by the following threshold sub-parameters: a speed vector threshold, an energy threshold, and a distance threshold. These threshold sub-parameters are used by the data processing unit 20 for recalculating at least one of the target location parameters, and the sub-parameters thereof, as shown in step 125 of Fig. 3. For example, if the UAV's actual geographic location is too far from the target geographic location (as a result of a sudden blow of wind), so that it exceeds the distance threshold, the target route 30 and the target locations 32 thereof will be recalculated.

In step 130, the data processing unit 20 selects operative modes of the propulsion and energy generation arrangements and movement direction of the UAV 1 by performing optimization of the comparison parameters. The selected operative modes and the selected movement direction are based on the comparison parameters obtained in step 120. The step 130, in which the operative mode of the propulsion arrangement is selected, can also include controlling power supply to the propulsion arrangement in its propulsion mode, i.e., increasing or reducing the power supply to the motor-generator 10. By reducing the power supply to zero, the propulsion arrangement can be reconfigured from the propulsion mode to the idle mode thereof.

In step 140, the data processing unit 20 obtains the selected operative modes of the propulsion and energy generation arrangements and the selected movement direction of the unmanned aerial vehicle, and controls navigation of the UAV 1 by instructing the propulsion and energy generation arrangements to operate in the selected operative modes and by instructing the direction control arrangement to control the UAV 1 to move in the selected movement direction.

The data processing unit 20 can be configured to perform the steps 110, 120, 130 and 140, or at least one of them in a repetitive manner upon variation of the actual geographic position of the UAV 1, or upon variation of any other actual route parameters.

The following are four examples which demonstrate the operation of the data processing unit 20 according to the steps 110 to 140:

Example 1:

This example demonstrates a situation in which the UAV's propulsion arrangement is in its propulsion mode, i.e. the motor-generator 10 receives an electric energy from the battery 14, and rotates the propeller 12 for driving the UAV 1, while the UAV's energy generation arrangement is in its idle mode, i.e., energy is not generated by the motor-generator 10 and not stored in the battery 14.

By performing the comparison in step 120, according to Example 1, the data processing unit 20 can calculate comparison parameters which may reflect the following situation:

- the actual speed vector direction is equal to the target speed vector direction of the preferred target speed vector;
- the actual speed vector size is larger than the target speed vector size of the preferred target speed vector; and
- the actual energy level is within the target energy range;

This situation means that the UAV 1 flies in the right direction, but too fast, and that its battery charged with enough electric power. The too fast upward movement of the UAV 1 may be a result of a strong stream of air (e.g., in an upstream), and in this situation, the electric power stored in the battery 14 may be saved by reducing power supply to the propulsion arrangement. This can be performed by the data processing unit, in steps 130 and 140 of the method 200, in which the UAV's propulsion arrangement is instructed to reduce power supply to motor-generator 10.

Example 2:

This example demonstrates a situation in which the UAV's propulsion arrangement is in its propulsion mode, i.e. the motor-generator 10 receives an electric energy from the battery 14, and rotates the propeller 12 for driving the UAV 1, while the UAV's energy generation arrangement is in its idle mode, i.e., energy is not generated by the motor-generator 10 and not stored in the battery 14.

By performing the comparison in step 120, according to Example 1, the data processing unit 20 can calculate comparison parameters which may reflect the following situation:

- the actual speed vector direction is equal to the target speed vector direction of the preferred target speed vector;
- the actual speed vector size is larger than the target speed vector size of the preferred target speed vector; and

- the actual energy level is below the target energy range;

This situation means that the UAV 1 flies in the right direction, but too fast, and that its battery 14 has to be charged. The too fast movement of the UAV may be a result of a strong stream of air (e.g., in an upstream), and in this situation, the battery should be charged by the energy generation arrangement. This is performed by the data processing unit, which is operated in steps 130 and 140 of the method 200 to select the idle mode of the propulsion arrangement, and to select the energy generation mode of the energy generation arrangement, and to instruct the propulsion and energy arrangements accordingly.

Example 3:

This example demonstrates a situation in which the UAV's propulsion arrangement is in its idle mode, i.e. the propeller 12 is not rotated due to an electric energy provided thereto from the battery 14, and the UAV's energy generation arrangement is in its energy generation mode, i.e., energy is generated by the motor-generator 10 and stored in the battery 14.

By performing the comparison of step 120, the data processing unit 20 calculated comparison parameters which reflect the following situation:

- the actual speed vector direction is equal to the target speed vector direction of the preferred target speed vector;
- the actual speed vector size is smaller than the target speed vector size of the preferred target speed vector; and
- the actual energy level is above the target energy range;

This situation means that the UAV 1 flies in the right direction, but too slow, and that its battery is charged with extra electric power, which can be used for propelling the UAV. In this situation, the propulsion arrangement should be operated in its propulsion mode, and the energy generation arrangement should operate in the idle mode. This is performed by the data processing unit 20, which is operated in steps 130 and 140 to select the above appropriate operation modes of the propulsion and energy generation arrangements, and to instruct the propulsion and energy arrangements accordingly.

CLAIMS:

1. An unmanned aerial vehicle having a task to be fulfilled, the unmanned aerial vehicle comprising:
 - a. a rechargeable energy storage unit;
 - b. a propulsion arrangement configured to operate in at least two operative modes: a propulsion mode in which said propulsion arrangement is configured to use energy from at least said energy storage unit for driving said unmanned aerial vehicle; and an idle mode in which said propulsion arrangement is inoperative;
 - c. an energy generation arrangement configured to operate in at least two operative modes: an energy generation mode in which said energy generation arrangement is configured to convert kinetic energy of streams of air in the surrounding of said unmanned aerial vehicle, into another form of a collected energy, and store at least a part of the collected energy in the energy storage unit; and an idle mode in which said energy generation arrangement is inoperative;
 - d. a direction control arrangement configured to control movement direction of the unmanned aerial vehicle; and
 - e. a data processing unit in communication with the propulsion and energy generation arrangements and with said direction control arrangement, said data processing unit being configured to perform energy management of the unmanned aerial vehicle based on comparison of actual route parameters related to a real-time state of the unmanned aerial vehicle, with target route parameters including data related to target energy level in said energy storage unit, by: determining, in view said target route parameters, selected operative modes and selected movement direction based on said comparison; and controlling navigation of said unmanned aerial vehicle at least by instructing said propulsion and energy generation arrangements to operate in the selected operative modes and instructing said direction control arrangement to control the unmanned aerial vehicle to move in the selected movement direction.
2. An unmanned aerial vehicle according to Claim 1, wherein said another form of collected energy is an electric energy.

3. An unmanned aerial vehicle according to Claim 2, wherein the propulsion and energy generation arrangements comprise a common electric motor-generator with a common propeller rotatably connected thereto, and said energy storage unit is a rechargeable electric battery in which said electric energy is stored.
4. An unmanned aerial vehicle according to Claim 3, wherein when the propulsion arrangement is in its propulsion mode, the energy storage unit supplies the electric energy to the electric motor-generator for rotating the propeller and thereby driving the unmanned aerial vehicle, and the energy generation arrangement is in its idle mode in which electric energy is not generated by the electric motor-generator and not stored in the energy storage unit; and wherein when the energy generation arrangement is in its energy generation mode, the propeller is rotated by the streams of air in the surrounding of the unmanned aerial vehicle for converting the kinetic energy thereof into the electric energy via the electric motor-generator and storing the electric energy in the energy storage unit, and the propulsion arrangement is in its idle mode in which electric energy is not supplied from the energy storage unit to the electric motor-generator for rotating the propeller to drive the UAV.
5. An unmanned aerial vehicle according to any one of the preceding claims, wherein said actual route parameters include: a task timetable, an actual speed vector, an actual energy level, and an actual geographic position; and wherein said target route parameters include a plurality of task location parameters, each related to a target location and being characterized by sub-parameters including: a target speed vector range; a target energy range related to the target energy level; and a target geographic position.
6. An unmanned aerial vehicle according to Claim 5, wherein said unmanned aerial vehicle further comprises:
 - a. a geographical position measuring arrangement, in communication with said data processing unit, configured for providing said actual geographic position;

- b. a speed measuring arrangement, in communication with said data processing unit, configured for providing said actual speed vector of the unmanned aerial vehicle; and
 - c. at least one energy level measuring arrangement, in communication with said data processing unit, configured for measuring said actual energy level in said energy storage unit.
7. An unmanned aerial vehicle according to Claim 6, wherein said actual speed vector is calculated by said speed measuring arrangement according to variation in time of said actual geographic position.
8. An unmanned aerial vehicle according to any one of Claims 5 to 7, wherein said data processing unit is further configured for performing said comparison by calculating comparison parameters by comparing: the actual geographic position with the target geographic position of a closest target location, the actual speed vector with the target speed vector range of the closest target location, and the actual energy level with the target energy range of the closest target location.
9. An unmanned aerial vehicle according to any one of Claims 5 to 8, wherein said data processing unit is further configured for selecting the selected operative modes of the propulsion and energy generation arrangements and the selected movement direction of the unmanned aerial vehicle by performing optimization of the comparison parameters.
10. An unmanned aerial vehicle according to Claim 9, wherein said data processing unit is configured to perform the comparison and the selection of the selected operative modes in a repetitive manner upon variation of the actual geographic position.
11. An unmanned aerial vehicle according to any one of Claims 5 to 10, wherein said target geographic position of each of said task location parameters is calculated according to said task timetable and a map of airstreams which includes upstreams and downstreams.

12. An unmanned aerial vehicle according to any one of Claims 5 to 11, wherein each of said plurality of task location parameters is further characterized by a speed vector threshold, an energy threshold, and a distance threshold, so that when at least one of said comparison parameters is inconsistent with at least one of: the speed vector threshold, the energy threshold, and the distance threshold, said data processing unit is configured to recalculate at least one of said target location parameters.
13. An unmanned aerial vehicle according to any one of Claims 5 to 12, when dependent on Claim 3, wherein the instruction of the propulsion arrangement further includes controlling power supply to the motor-generator.
14. An unmanned aerial vehicle according to any one of Claims 5 to 13, wherein said actual speed vector is characterized by an actual speed vector direction and size, and said target speed vector range includes a plurality of target speed vectors, each having a target speed vector direction and size; and wherein said comparison is performed by selecting a preferred target speed vector of said target speed vectors and comparing said actual speed vector direction and size with said target speed vector direction and size of the preferred target speed vector.
15. An unmanned aerial vehicle according to Claim 14, when dependent on Claim 3, wherein when the following conditions are fulfilled:
 - a. the actual speed vector direction equals to the target speed vector direction of the preferred target speed vector;
 - b. the actual speed vector size is larger than the target speed vector size of the preferred target speed vector;
 - c. the actual energy level is below or within the target energy range;
 - d. the propulsion arrangement is in its propulsion mode; and
 - e. the energy generation arrangement is in its idle mode;the data processing unit is configured to perform one of:
 - (i) reducing power supply to the motor-generator; and

- (ii) selecting the idle mode of the propulsion arrangement and the energy generation mode of the energy generation arrangement, and instructing said propulsion and energy arrangements accordingly.
16. An unmanned aerial vehicle according to any one of Claims 14 and 15, when dependent on Claim 3, wherein when the following conditions are fulfilled:
- a. the actual speed vector direction equals to the target speed vector direction of the preferred target speed vector;
 - b. the actual energy level is within or above the target energy range;
 - c. the actual speed vector size is smaller than the target speed vector size of the preferred target speed vector;
 - d. the propulsion arrangement is in its idle mode; and
 - e. the energy generation arrangement is in its generation mode;
- the data processing unit is configured to perform any one of:
- (i) increasing power supply to the motor-generator; and
 - (ii) selecting the idle mode of the energy generation arrangement and the propulsion mode of said propulsion arrangement.
17. An unmanned aerial vehicle according to any one of the preceding claims, further comprising at least one external energy generation arrangement configured to operate in at least two operative modes: an energy generation mode in which said energy generation arrangement is configured to convert energy from sources of energy being different from streams of air in the surrounding of the unmanned aerial vehicle, into another form of generated energy, and store at least a part of said collected energy in the energy storage unit; and an idle mode in which said external energy generation arrangement is inoperative; wherein said data processing unit is further configured to perform energy management by selecting the operative mode of the at least one external energy generation arrangement and by instructing the external energy generation arrangement to operate in the selected operative mode, accordingly.
18. A method for operating an unmanned aerial vehicle having a task to be fulfilled, comprising steps of:

- a. providing an unmanned aerial vehicle comprising: a rechargeable energy storage unit; a propulsion arrangement; an energy generation arrangement; a direction control arrangement; and a data processing unit in communication with the propulsion and energy generation arrangements and with the direction control arrangement;
 - b. operating said propulsion arrangement in at least two operative modes: a propulsion mode in which said propulsion arrangement is configured to use energy from at least said energy storage unit for driving said unmanned aerial vehicle; and an idle mode in which said propulsion arrangement is inoperative;
 - c. operating said energy generation arrangement in at least two operative modes: an energy generation mode in which said energy generation arrangement is configured to convert kinetic energy of streams of air in the surrounding of said unmanned aerial vehicle, into another form of a collected energy, and store at least a part of the collected energy in the energy storage unit; and an idle mode in which said energy generation arrangement is inoperative;
 - d. controlling movement direction of the unmanned aerial vehicle at an actual location thereof by the direction control arrangement; and
 - e. operating said data processing unit for performing energy management of the unmanned aerial vehicle based on comparison of actual route parameters related to a real-time state of the unmanned aerial vehicle, with target route parameters including data related to target energy level in said energy storage unit, by steps of:
 - (i) determining, in view said target route parameters, selected operative modes and selected movement direction based on said comparison; and
 - (ii) controlling navigation of said unmanned aerial vehicle at least by instructing said propulsion and energy generation arrangements to operate in the selected operative modes and instructing said direction control arrangement to control the unmanned aerial vehicle to move in the selected movement direction.
19. A method according to Claim 18, wherein said another form of collected energy is an electric energy.

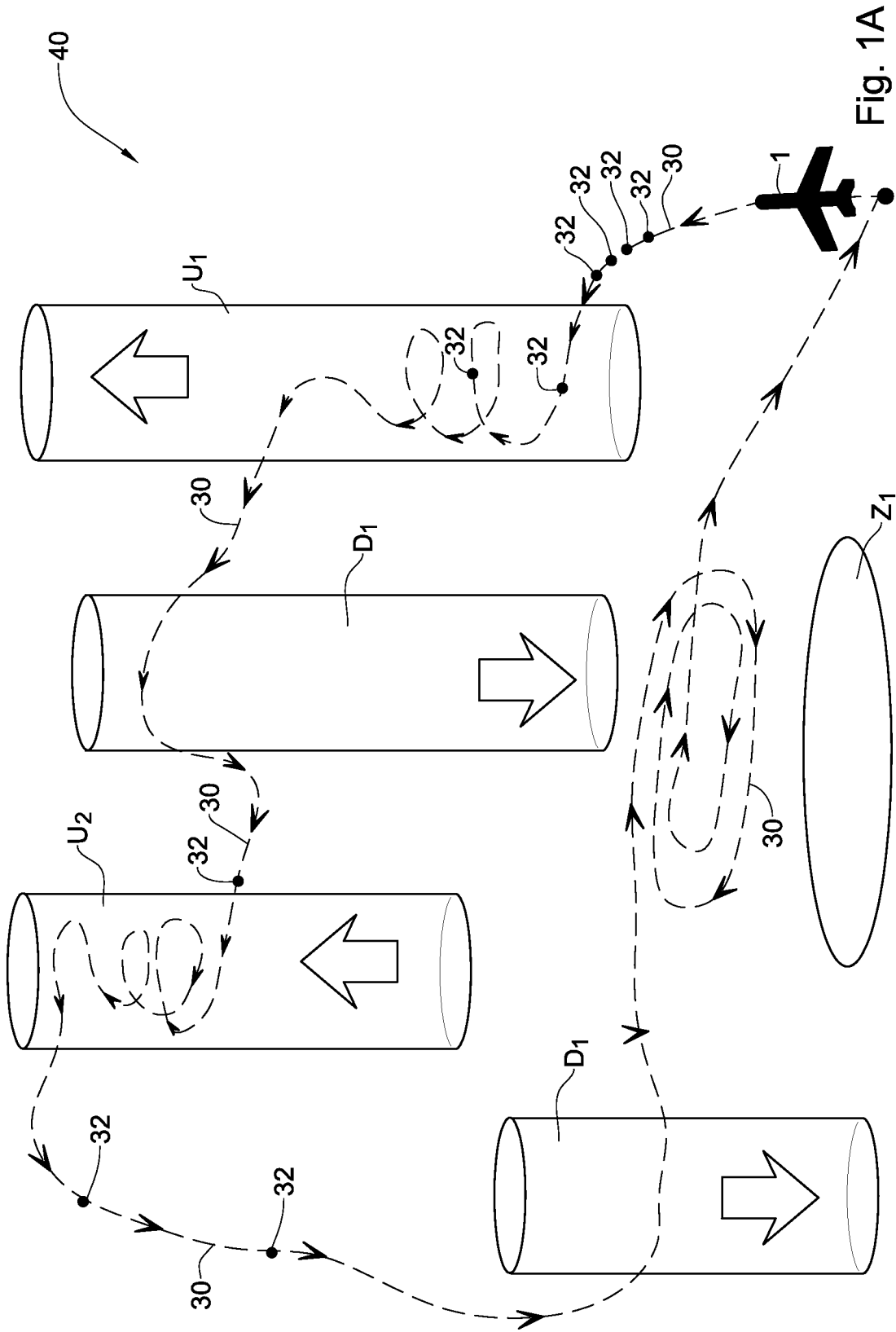
20. A method according to Claim 19, wherein the propulsion and energy generation arrangements comprise a common electric motor-generator with a common propeller rotatably connected thereto, and said energy storage unit is a rechargeable electric battery in which said electric energy is stored.
21. A method according to Claim 20, wherein when the propulsion arrangement is in its propulsion mode, the energy storage unit supplies the electric energy to the electric motor-generator for rotating the propeller and thereby driving the unmanned aerial vehicle, and the energy generation arrangement is in its idle mode in which electric energy is not generated by the electric motor-generator; and wherein when the energy generation arrangement is in its energy generation mode, the propeller is rotated by the streams of air in the surrounding of the unmanned aerial vehicle for converting the kinetic energy thereof into the electric energy via the electric motor-generator and storing the electric energy in the energy storage unit, and the propulsion arrangement is in its idle mode in which electric energy is not supplied from the energy storage unit to the electric motor-generator.
22. A method according to any one of Claims 18 to 21, wherein said actual route parameters include: a task timetable, an actual speed vector, an actual energy level, and an actual geographic position; and wherein said target route parameters include a plurality of task location parameters, each related to a target location and being characterized by sub-parameters including: a target speed vector range; a target energy range related to the target energy level; and a target geographic position.
23. The method according to Claim 22, wherein said unmanned aerial vehicle further comprises:
 - a. a geographical position measuring arrangement, in communication with said data processing unit, configured for providing said actual geographic position;
 - b. a speed measuring arrangement, in communication with said data processing unit, configured for providing said actual speed vector of the unmanned aerial vehicle; and

- c. at least one energy level measuring arrangement, in communication with said data processing unit, configured for measuring an actual energy level in said energy storage unit.
24. A method according to Claim 23, further comprising a step of calculating the actual speed vector by the speed measuring arrangement according to variation in time of the actual geographic position.
25. A method according to any one of Claims 22 to 24, wherein said data processing unit is further configured for performing said comparison by a step of calculating comparison parameters by comparing: the actual geographic position with the target geographic position of a closest target location, the actual speed vector with the target speed vector range of the closest target location, and the actual energy level with the target energy range of the closest target location.
26. A method according to any one of Claims 22 to 25, wherein said data processing unit is further configured for performing a step of selecting the selected operative modes of the propulsion and energy generation arrangements and the selected movement direction of the unmanned aerial vehicle by performing optimization of the comparison parameters.
27. A method according to Claim 26, wherein said data processing unit is configured to perform the comparison and the selection of the selected operative modes in a repetitive manner upon variation of the actual geographic position.
28. A method according to any one of Claims 22 to 27, wherein said target geographic position of each of said task location parameters is calculated according to said task timetable and a map of airstreams which includes upstreams and downstreams.
29. A method according to any one of Claims 22 to 28, wherein each of said plurality of task location parameters is further characterized by a speed vector threshold, an energy threshold, and a distance threshold, so that when at least

one of said comparison parameters is inconsistent with at least one of: the speed vector threshold, the energy threshold, and the distance threshold, said data processing unit is configured to recalculate at least one of said target location parameters.

30. A method according to any one of claims 22 to 29, when dependent on Claim 20, wherein the instruction of the propulsion arrangement further includes controlling power supply to the motor-generator.
31. A method according to any one of Claims 22 to 30, wherein said actual speed vector is characterized by an actual speed vector direction and size, and said target speed vector range includes a plurality of target speed vectors, each having a target speed vector direction and size; and wherein said comparison is performed by selecting a preferred target speed vector of said target speed vectors and comparing said actual speed vector direction and size with said target speed vector direction and size of the preferred target speed vector.
32. A method according to Claim 31, when dependent on Claim 20, wherein when the following conditions are fulfilled:
 - a. the actual speed vector direction equals to the target speed vector direction of the preferred target speed vector;
 - b. the actual speed vector size is larger than the target speed vector size of the preferred target speed vector;
 - c. the actual energy level is below or within the target energy range;
 - d. the propulsion arrangement is in its propulsion mode; and
 - e. the energy generation arrangement is in its idle mode;the data processing unit is configured to perform one of:
 - (i) reducing power supply to the motor-generator; and
 - (ii) selecting the idle mode of the propulsion arrangement and the energy generation mode of the energy generation arrangement, and instructing said propulsion and energy arrangements accordingly.
33. A method according to any one of Claims 31 and 32, when dependent on Claim 20, wherein when the following conditions are fulfilled:

- a. the actual speed vector direction equals to the target speed vector direction of the preferred target speed vector;
 - b. the actual energy level is within or above the target energy range;
 - c. the actual speed vector size is smaller than the target speed vector size of the preferred target speed vector;
 - d. the propulsion arrangement is in its idle mode; and
 - e. the energy generation arrangement is in its generation mode;
the data processing unit is configured to perform any one of:
 - (i) increasing power supply to the motor-generator; and
 - (ii) selecting the idle mode of the energy generation arrangement and the propulsion mode of said propulsion arrangement.
- 34.** A method according to any one of Claims 18 to 33, further comprising at least one external energy generation arrangement configured to operate in at least two operative modes: an energy generation mode in which said energy generation arrangement is configured to convert energy from sources of energy being different from streams of air in the surrounding of the unmanned aerial vehicle, into another form of generated energy, and store at least a part of said collected energy in the energy storage unit; and an idle mode in which said external energy generation arrangement is inoperative; wherein said data processing unit is further configured to perform energy management by selecting the operative mode of the at least one external energy generation arrangement and by instructing the external energy generation arrangement to operate in the selected operative mode, accordingly.



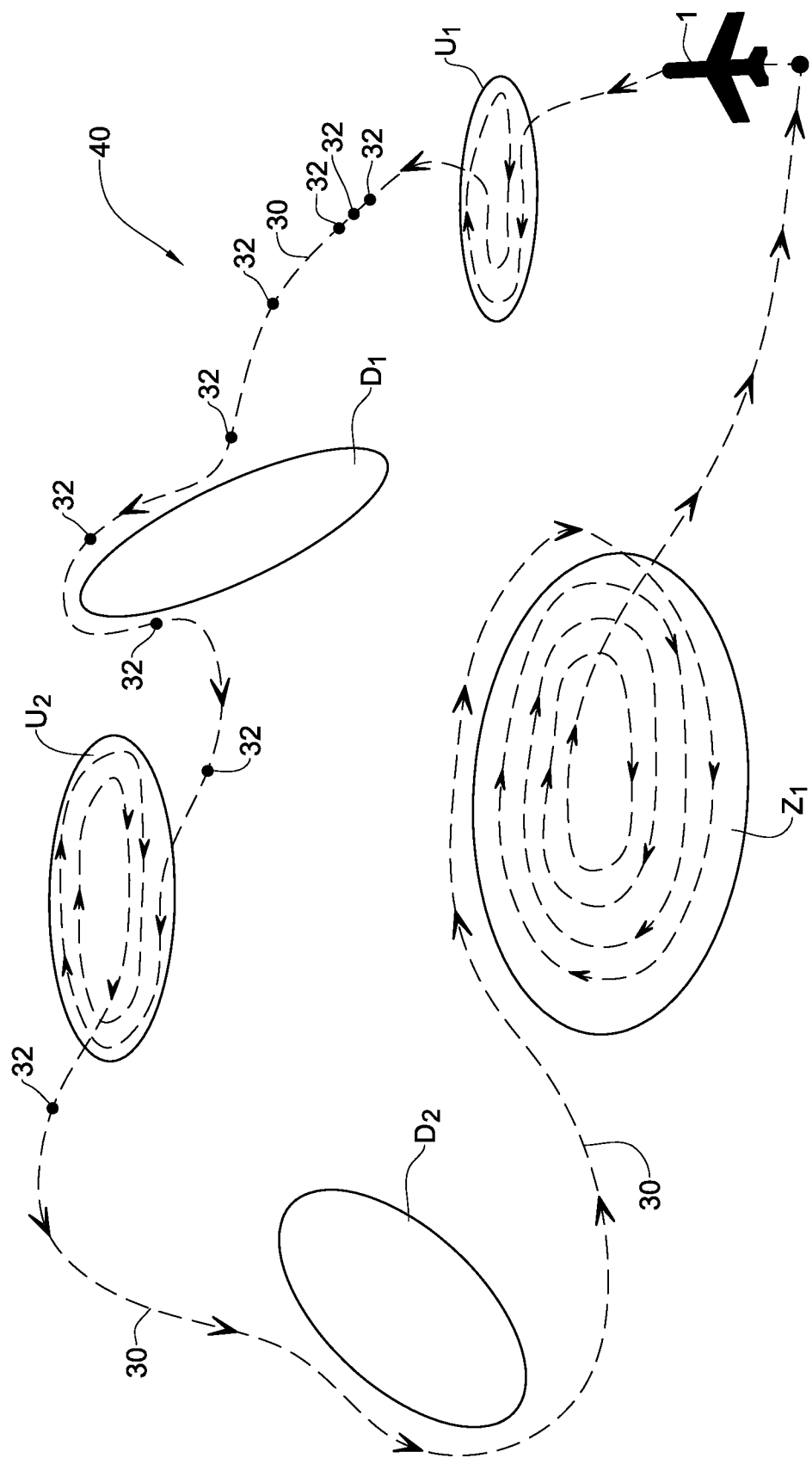


Fig. 1B

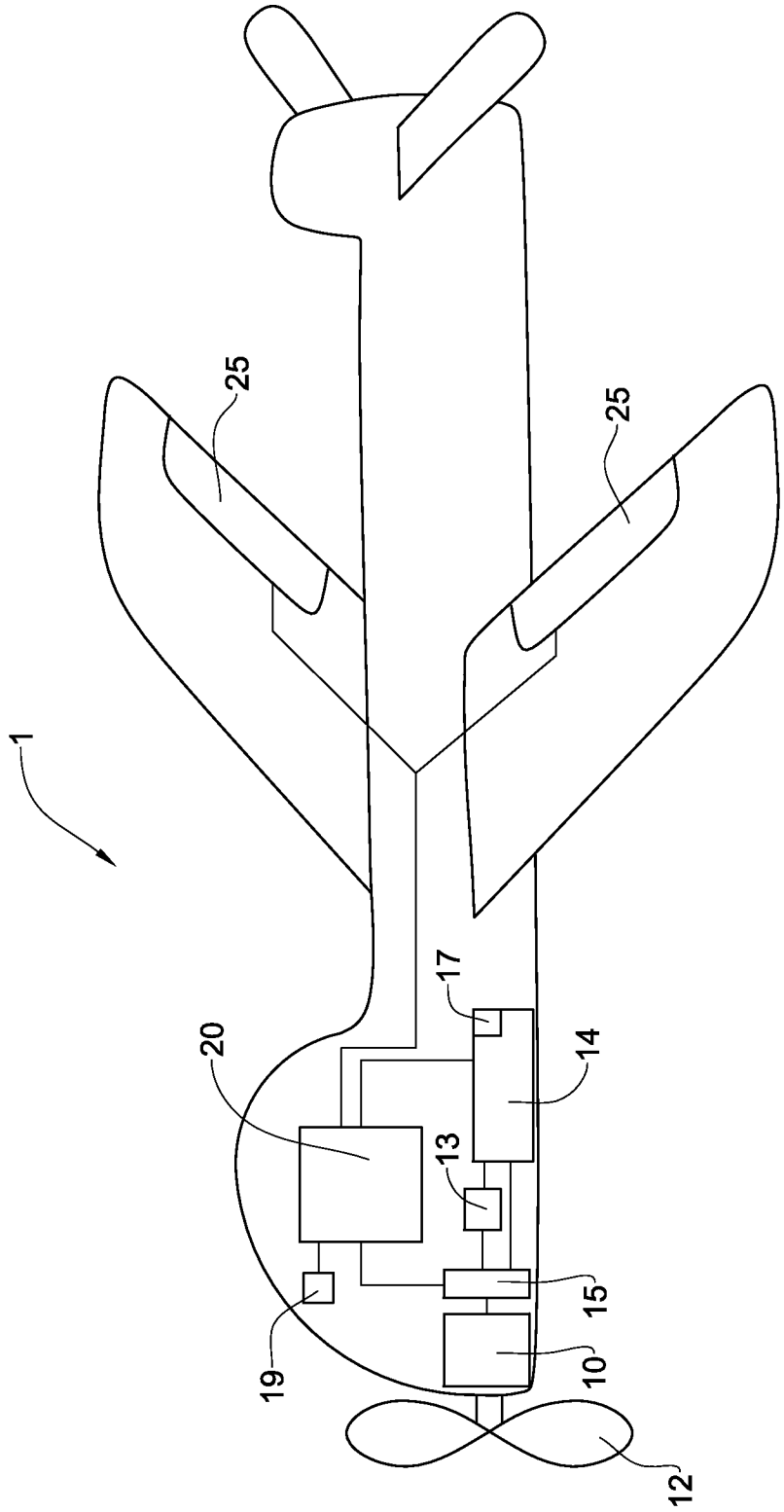


Fig. 2

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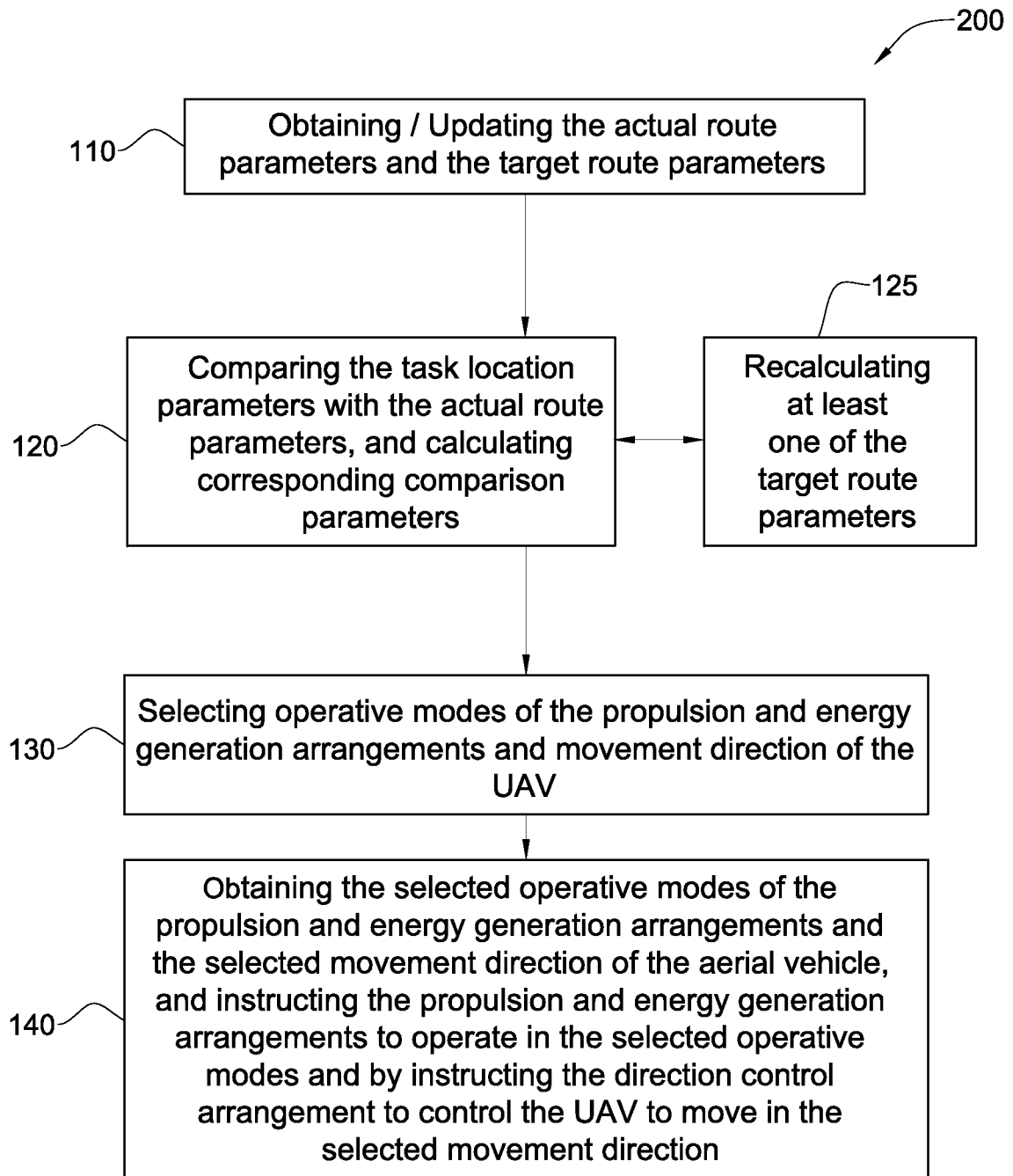


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IL2013/050636

A. CLASSIFICATION OF SUBJECT MATTER IPC (2013.01) B64C 31/00, G05D 1/00 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC (2013.01) B64C 31/00, G05D 1/00 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) Databases consulted: THOMSON INNOVATION, Esp@cenet, Google Patents, FamPat database Search terms used: UAV, energy, recharge, direction, control		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 12 Nov 2013		Date of mailing of the international search report 12 Nov 2013
Name and mailing address of the ISA: Israel Patent Office Technology Park, Bldg.5, Malcha, Jerusalem, 9695101, Israel Facsimile No. 972-2-5651616		Authorized officer ROASH Yoaela Telephone No. 972-2-5657807

INTERNATIONAL SEARCH REPORT

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