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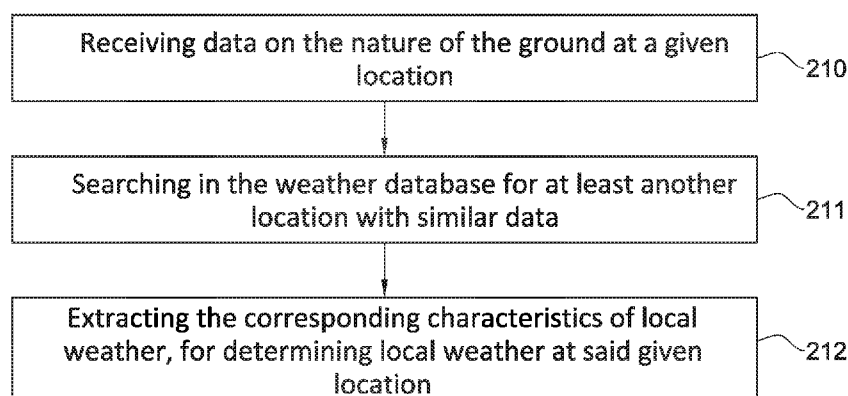


Fig. 21

(57) Abstract: A system for the measurement of weather comprises a sensor configured to sense data comprising data indicative of the geometrical configuration of a flexible airfoil of an air vehicle, and a controller configured to extract data indicative of the geometrical configuration of the airfoil in operation from the sensed data, and determine characteristics of local weather based at least on said extracted data. A system for the measurement of weather comprises a load sensor mounted on a suspension line attached to a flexible airfoil of an air vehicle, for measuring the load of the suspension line, and a controller configured to determine characteristics of local weather based at least on the load measured on the suspension line of the air vehicle in operation. A weather database comprises information on a correlation between data indicative of the nature of the ground at a plurality of locations and characteristics of the local weather at these locations.



SYSTEMS AND METHODS OF MEASURING AND ANALYSING WEATHER

PRIORITY

The present patent applications claims priority of IL 245668 filed on May 16th, 2016.

TECHNICAL FIELD

The presently disclosed subject matter relates to a solution for measuring and analysing characteristics of local weather.

BACKGROUND

In various technical fields, it is important to measure characteristics of the local weather.

In particular, the flight path of air vehicles needs to be controlled during operation of the air vehicle, and/or planned in advance, based on the knowledge of characteristics of local weather which includes characteristics of turbulence that may be encountered by such air vehicles.

There is a need to propose new methods and systems for measuring and analysing characteristics of local weather.

GENERAL DESCRIPTION

In accordance with certain aspects of the presently disclosed subject matter, there is provided a system for the measurement of weather, comprising at least a sensor configured to sense data comprising data indicative of the geometrical configuration of a flexible airfoil of an air vehicle, and at least a controller configured to extract data indicative of the geometrical configuration of the airfoil in operation from the sensed data, and determine characteristics of local weather based at least on said extracted data.

In accordance with certain aspects of the presently disclosed subject matter, there is provided a system for the measurement of weather, comprising at least a load sensor mounted on at least a suspension line attached to a flexible airfoil of an air vehicle, for measuring the load of the suspension line, and at least a controller

configured to determine characteristics of local weather based at least on the load measured on the suspension line of the air vehicle in operation.

According to some embodiments, the characteristics of local weather comprise at least one of an amplitude, a frequency, a direction, and a volume of a turbulence. According to some embodiments, the controller is configured to determine characteristics of the dynamics of the geometrical configuration of the airfoil during operation of the air vehicle in order to determine characteristics of the local weather. According to some embodiments, the controller is configured to determine characteristics of the dynamics of the load of the suspension line during operation of the air vehicle in order to determine characteristics of the local weather. According to some embodiments, the controller is configured to compare at least part of the extracted data with at least a reference configuration representing an operation of the airfoil under normal weather conditions, and to determine characteristics of the local weather based at least on said comparison. According to some embodiments, the controller is configured to determine an offset of the airfoil and/or a deformation of the airfoil, and to calculate the characteristics of the local weather based on said determination. According to some embodiments, the controller is configured to determine characteristics of local weather during operation of the air vehicle on the ground and/or in the air. According to some embodiments, the sensor comprises at least one of an image sensor and an electromagnetic waves based sensor configured to measure data indicative of the geometrical configuration of the airfoil based on the emission of electromagnetic waves towards the airfoil. According to some embodiments, the controller is configured to build a weather database based on said determination of the characteristics of the local weather at a plurality of locations. According to some embodiments, the weather database comprises, for each of a plurality of locations, characteristics of local weather and data indicative of the nature of the ground at said location. According to some embodiments, the weather database comprises, for each of a plurality of locations, characteristics of a turbulence measured by the system, data indicative of the ground topography at said location and data indicative of general weather conditions. According to some embodiments, the controller is configured to build a weather database which correlates characteristics of the local weather as measured by the system at a plurality of locations, with data indicative of the nature of the ground at said locations and/or data indicative of general weather conditions at said locations. According to some embodiments, the

controller is configured to determine, based at least on said weather database, characteristics of local weather at a given location. According to some embodiments, this determination is performed even if said given location is not part of the database, wherein the controller is configured to determine characteristics of local weather at said given location based on said weather database, data indicative of the nature of the ground at said given location and/or data indicative of general weather conditions at said given location. According to some embodiments, a communication unit is used for transmitting characteristics of local weather as measured to other air vehicles. According to some embodiments, the controller is configured to control at least an actuator for controlling the flight of the air vehicle based on the characteristics of local weather calculated by the system. According to some embodiments, there is proposed an air vehicle comprising a flexible airfoil, at least a suspension line attached to said airfoil and a system for the measurement of weather.

These embodiments can be combined according to any of their possible technical combination.

In accordance with some aspects of the presently disclosed subject matter, there is provided a computer-implemented controller operatively coupled to at least a sensor configured to sense data comprising data indicative of the geometrical configuration of a flexible airfoil of an air vehicle, the controller being configured to extract data indicative of the geometrical configuration of the airfoil in operation from the sensed data, and determine characteristics of local weather based at least on said extracted data.

In accordance with some aspects of the presently disclosed subject matter, there is provided a computer-implemented controller operatively coupled to at least a load sensor mounted on at least a suspension line attached to a flexible airfoil of an air vehicle, the controller being configured to determine characteristics of local weather based at least on the load measured on the suspension line of the air vehicle in operation.

In accordance with some aspects of the presently disclosed subject matter, there is provided a weather database comprising characteristics of local weather for a plurality of locations, data indicative of the nature of the ground at said plurality of locations, wherein the weather database comprises information on a correlation between the data indicative of the nature of the ground at said plurality of locations and characteristics of the local weather at said plurality of locations.

According to some embodiments, the weather database further comprises data indicative of general weather conditions at said plurality of locations. According to some embodiments, the characteristics of local weather comprise at least one of an amplitude, a frequency, a direction, and a volume of a turbulence.

These embodiments can be combined according to any of their possible technical combination.

In accordance with some aspects of the presently disclosed subject matter, there is provided a system for determining weather, the system comprising a controller configured to determine characteristics of local weather at a plurality of locations based at least on said weather database and data indicative of the nature of the ground at said locations.

According to some embodiments, the controller is configured to, for a given location with given data indicating the nature of the ground at said given location, search in the weather database at least another location for which the data indicating the nature of the ground at said another location match said given data indicating the nature of the ground at said given location, and extract the characteristics of the local weather at said location from the weather database to determine the local weather at said another location. According to some embodiments, the controller is configured to, for a given location with given data indicating the nature of the ground at said given location and given general weather conditions: search in the weather database at least another location for which the data indicating the nature of the ground at said another location match said given data indicating the nature of the ground at said given location according to a matching criterion, and the given general weather conditions stored in the weather database for said another location match the general weather conditions stored in the database at said given location according to a matching criterion, and extract the characteristics of the local weather at said another location from the weather database to determine the local weather at said given location.

In accordance with some aspects of the presently disclosed subject matter, there is provided a method of measuring weather, comprising sensing data comprising data indicative of the geometrical configuration of a flexible airfoil of an air vehicle with at least a sensor, extracting data indicative of the geometrical configuration of the airfoil in operation from the sensed data, and determining characteristics of local weather based at least on said extracted data.

In accordance with some aspects of the presently disclosed subject matter, there is provided a method of measuring weather, comprising sensing load of at least a suspension line attached to a flexible airfoil of an air vehicle, with at least a load sensor, and determining characteristics of local weather based at least on the load measured on the suspension line of the air vehicle in operation.

According to some embodiments, the characteristics of local weather comprise at least one of an amplitude, a frequency, a direction, and a volume of a turbulence. According to some embodiments, it is provided the steps comprising determining characteristics of the dynamics of the geometrical configuration of the airfoil during operation of the air vehicle in order to determine characteristics of the local weather. According to some embodiments, it is provided the steps comprising determining characteristics of the dynamics of the load of the suspension line during operation of the air vehicle in order to determine characteristics of the local weather. According to some embodiments, it is provided the steps comprising comparing at least part of the extracted data with at least a reference configuration representing a normal operation of the airfoil, and determining characteristics of the local weather based at least on said comparison. According to some embodiments, it is provided the steps comprising determining an offset of the airfoil and/or a deformation of the airfoil, and calculating the characteristics of the local weather based on said determination. According to some embodiments, it is provided the steps comprising determining characteristics of local weather during operation of the air vehicle on the ground and/or in the air. According to some embodiments, it is provided the steps comprising building a weather database based on said determination of the characteristics of the local weather at a plurality of locations. According to some embodiments, the weather database comprises, for each of a plurality of locations, characteristics of local weather and data indicative of the nature of the ground at said location. According to some embodiments, the weather database comprises, for each of a plurality of locations, characteristics of a turbulence, data indicative of the ground topography at said location and data indicative of general weather conditions. According to some embodiments, it is provided the steps comprising building a weather database which correlates characteristics of the local weather as measured by the system at a plurality of locations, with data indicative of the ground topography at said locations and/or data indicative of general weather conditions at said locations. According to some embodiments, it is provided the steps comprising determining, based on said weather

database, characteristics of local weather at a given location. According to some embodiments, this determination is performed even if said given location is not part of the weather database, and comprises determining characteristics of local weather at said given location based on said weather database, data indicative of the nature of the ground at said given location and/or data indicative of general weather conditions at said given location. According to some embodiments, it is provided the steps comprising transmitting characteristics of local weather as measured to other air vehicles. According to some embodiments, it is provided the steps comprising controlling at least an actuator for controlling the flight of the air vehicle based on the characteristics of local weather calculated by the system.

These embodiments can be combined according to any of their possible technical combination.

In accordance with some aspects of the presently disclosed subject matter, there is provided a method of building a weather database, comprising storing characteristics of local weather for a plurality of locations, data indicative of the nature of the ground at said plurality of locations, and information on a correlation between the data indicative of the nature of the ground at said plurality of locations and characteristics of the local weather at said plurality of locations.

According to some embodiments, the method comprises storing data indicative of general weather conditions at said plurality of locations in the weather database.

In accordance with some aspects of the presently disclosed subject matter, there is provided a method of determining weather, comprising determining characteristics of local weather at a plurality of locations based at least on said weather database and data indicative of the nature of the ground at said locations.

According to some embodiments, the method comprises, for a given location with given data indicating the nature of the ground at said given location: searching in the weather database for at least another location for which the data indicative of the nature of the ground at said another location match said given data indicative of the nature of the ground at said given location, and extracting the characteristics of the local weather at said location from the weather database to determine the local weather at said another location.

According to some embodiments, the method comprises, for a given location with given data indicating the nature of the ground at said given location and given

general weather conditions, searching in the weather database for at least another location for which the data indicative of the nature of the ground at said another location match said given data indicative of the nature of the ground at said given location according to a matching criterion, and the given general weather conditions stored in the weather database for said another location match the general weather conditions stored in the database at said given location according to a matching criterion, and extracting the characteristics of the local weather at said another location from the weather database to determine the local weather at said given location.

These embodiments can be combined according to any of their possible technical combination.

In accordance with some aspects of the presently disclosed subject matter, there is provided a method of planning the flight path of an air vehicle, comprising determining characteristics of local weather on a flight path of the air vehicle, based on said weather database and data indicative of the nature of the ground on said flight path, and planning the flight path based on said determination.

In accordance with some aspects of the presently disclosed subject matter, there is provided a non-transitory storage device readable by a machine, tangibly embodying a program of instructions executable by the machine to perform a method according to any of the embodiments described previously.

According to some embodiments, the solution improves the flight safety of air vehicles.

According to some embodiments, the solution increases the life length of air vehicles.

According to some embodiments, the solution provides an efficient and innovative measurement of characteristics of local weather.

According to some embodiments, the solution provides a measurement of characteristics of local weather at various locations and various altitudes.

According to some embodiments, the solution relies on data measurement which reflects, in real time or close to real time, the characteristics of local weather.

According to some embodiments, the solution detects a correlation between the characteristics of local weather and the nature of the ground (such as its topography), and/or general weather conditions.

According to some embodiments, the solution allows the creation of a weather database.

According to some embodiments, the solution allows an analysis (which includes e.g. a real time analysis or an *a priori* analysis/prediction) of characteristics of local weather for given locations, even if measurements of the characteristics of local weather were not performed at said locations.

According to some embodiments, the solution allows an analysis (which includes e.g. a real time analysis or an *a priori* analysis/prediction) of characteristics of local weather at given locations based on the topography of said locations and, if necessary, based on given general weather conditions at said locations.

According to some embodiments, the solution allows an analysis (which includes e.g. a real time analysis or an *a priori* analysis/prediction) of characteristics of local weather for planning the flight path of one or more air vehicles.

According to some embodiments, the solution allows the calculation of the characteristics of local weather by an air vehicle and the transmission of the results to other air vehicles.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it can be carried out in practice, embodiments will be described, by way of non-limiting embodiments, with reference to the accompanying drawings, in which:

- **Fig. 1** illustrates an embodiment of an air vehicle which can embed a system for the measurement of weather;
- **Fig. 2** illustrates a particular embodiment of the air vehicle of **Fig. 1**;
- **Fig. 3** illustrates another particular embodiment of the air vehicle of **Fig. 1**;
- **Fig. 4** illustrates an embodiment of a system for the measurement of weather;
- **Fig. 5** illustrates an embodiment of a method of measuring weather;
- **Fig. 6** illustrates embodiments for obtaining a reference configuration representing an operation of the air vehicle in a normal or reference local weather;
- **Fig. 7** illustrates a reference configuration for the airfoil, which comprises a contour defining the contour of the airfoil in normal local weather;

- **Fig. 7A** illustrates an offset of the airfoil due to the presence of turbulence;
- **Fig. 7B** illustrates a method of measuring weather based on the monitoring of the offset of the airfoil;
- **Fig. 8** illustrates a comparison of a sensed contour of an airfoil with a reference configuration;
- **Fig. 9** illustrates an embodiment in which visual markers are present on the airfoil;
- **Fig. 10** illustrates an embodiment of a method of measuring weather based on the detection of visual markers on the airfoil;
- **Fig. 10A** illustrates an embodiment of a reference configuration of a geometrical configuration of a portion of the sky surrounding the canopy;
- **Fig. 11** illustrates an embodiment of a geometrical configuration of a portion of the sky surrounding the airfoil in the case of turbulence;
- **Fig. 12** illustrates an embodiment of a method of measuring weather, based on the analysis of a geometrical configuration of the sky;
- **Fig. 13** illustrates an embodiment of a method of measuring weather, based on the analysis of load of suspension lines of the airfoil;
- **Fig. 14** illustrates an embodiment of a load sensor mounted on a suspension line of the airfoil;
- **Fig. 15** illustrates an embodiment of a curve representing the velocity of the turbulence in time at a given location, and the load measured on the suspension line of the air vehicle at said given location;
- **Fig. 16** illustrates an embodiment of a method of building a weather database;
- **Fig. 17** illustrates a turbulence which is caused by the presence of a mountain;
- **Fig. 18** illustrates a turbulence which is caused by the presence of a slope;
- **Fig. 19** illustrates an embodiment of a method of building a weather database which correlates the characteristics of local weather as measured to various data;
- **Fig. 19A** is a particular example of a correlation performed in the method of **Fig. 19**;
- **Figs. 20 to 22** illustrate embodiments of methods of determining weather based on the weather database;
- **Fig. 23** illustrates an embodiment of a method of planning the flight path of an air vehicle.

DETAILED DESCRIPTION

In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the invention. However, it will be understood by those skilled in the art that the presently disclosed subject matter may be practiced without these specific details. In other instances, well-known methods have not been described in detail so as not to obscure the presently disclosed subject matter.

Unless specifically stated otherwise, as apparent from the following discussions, it is appreciated that throughout the specification discussions utilizing terms such as "sensing", "extracting", "determining", "measuring", "comparing", "building", "predicting", "analysing" and "calculating", or the like, refer to the action(s) and/or process(es) of a processing unit that manipulate and/or transform data into other data, said data represented as physical, such as electronic, quantities and/or said data representing the physical objects.

The term "processing unit" covers any computing unit or electronic unit that may perform tasks based on instructions stored in a memory, such as a computer, a server, a chip, etc. It encompasses a single processor or multiple processors, which may be located in the same geographical zone or may, at least partially, be located in different zones and may be able to communicate together.

The term "non-transitory memory" as used herein should be expansively construed to cover any volatile or non-volatile computer memory suitable to the presently disclosed subject matter.

Embodiments of the presently disclosed subject matter are not described with reference to any particular programming language. It will be appreciated that a variety of programming languages may be used to implement the teachings of the presently disclosed subject matter as described herein.

Fig. 1 is a simplified representation of an air vehicle **10** which can embed a system for the measurement of weather as described later in the specification.

The air vehicle **10** can comprise a body **13** and an airfoil **11** connected to said body **13** by at least a suspension line **12**. Depending on the nature of the air vehicle **10**, the body **13** can include motors, a human or a non-human payload, a harness, etc (this list being not limitative).

The airfoil **11** is flexible and thus, as explained later in the specification, can reflect the characteristics of local weather.

The airfoil **11** is generally used to create lift.

Fig. 2 represents a particular embodiment of the air vehicle of **Fig. 1** in the form of a parachute.

In the present text, the expression “parachute” includes various types of parachutes, such as a parachute, a parafoil, a paraglider, a powered parachute or the like. Depending on the embodiments, it can include ascending parachutes or descending parachutes. Depending on the embodiments, it can be controlled by a pilot (human) or by an automatic control unit or uncontrolled (“free”) parachutes.

The parachute **20** comprises a canopy **21** (which is an example of an airfoil). The canopy **21** can have different forms, such as, but not limited to, rectangle, square, round, etc.

The parachute **20** can comprise suspension lines **22**, which are generally elongate lines which connect the canopy **21** to a payload **23** that is transported by the parachute **20**. The suspension lines **22** can be non rigid lines such as strings. Depending on the embodiments, at least part of the suspension lines **22** can be divided at their extremity into a plurality of lines connected to the canopy **21**.

The suspension lines can include lines which are used to support load, such as load bearing lines. The suspension lines can also include lines which are used for controlling the flight (e.g. direction, velocity, etc.) of the parachute. Some suspension lines can also be used for both supporting load and controlling the flight of the parachute.

According to some embodiments, depending on the position of the suspension lines with respect to the canopy, at least a subset of the suspension lines can be used as brake lines, and at least a subset of the of the suspension lines can be used for controlling acceleration and/or deceleration (such as by changing the angle of attack of the canopy, for example by lowering the leading edge with speed line or creating drag by the break lines), and at least a subset of the suspension lines can be used for controlling the flight trajectory of the parachute (for controlled parachutes). According to some embodiments, the suspension lines are divided into conventional subsets called “A lines”, “B lines”, “C lines” and “D lines” (break lines).

The payload **23** can include for instance a pilot, and/or an automatic pilot unit, and/or any required payload (such as any device or material to be transported by the parachute).

According to some embodiments, the parachute is deployed from the air (e.g. in the case of skydiving).

According to some embodiments, the parachute is first inflated and deployed from the ground, and then is launched in the air.

According to some embodiments, the parachute is already deployed and launched from the ground.

According to some embodiments, the parachute is a powered parachute which comprises at least a motor.

According to some embodiments, the parachute is a free parachute (uncontrolled parachute).

According to some embodiments, the parachute is controlled by a pilot, which can command the parachute e.g. through at least a subset of the suspension lines, or through manual actuators (such as lines, steering lines or risers) connected to said subset of suspension lines.

According to some embodiments, the parachute is controlled by an automatic pilot unit. A non limiting embodiment is depicted in **Fig. 3**. As shown, the automatic pilot unit **33** controls the suspension lines **32** connected to the canopy **31**, in order to control the flight of the parachute. The automatic pilot unit **30** can comprise a processing unit **34** and a storage (not represented).

The automatic pilot unit **30** can be connected to at least a subset of the suspension lines **32** through one or more electro-mechanical actuators such as linear servo-actuators, rotary servo-actuators or winch servo-actuators, which receive at least a signal computed by the automatic pilot unit **30** and apply a corresponding force to said suspension lines **32**. According to some embodiments, the automatic pilot unit **30** further controls at least a motor or a plurality of motors embedded in the parachute. This motorized parachute can include for instance a trike or other wheel frame that supports a payload which is hooked to the canopy.

Fig. 4 describes an embodiment of a system **40** for the measurement of weather, which can be (at least partly) embedded e.g. in the air vehicle comprising a flexible airfoil of **Figs. 1 to 3**.

As shown, according to some embodiments, the system **40** can comprise a controller **41** operating on a processing unit, a storage **43** which can include a non-transitory memory, and at least a sensor **42**.

In particular, the system **40** can comprise at least one of the following sensors **42**:

- at least a sensor configured to sense data indicative of the geometrical configuration of the flexible airfoil of the air vehicle. It includes e.g. an image sensor such as a camera. The image sensor can be a dedicated image sensor or a sensor existing on a device, such as (but not limited to) a smartphone. According to some embodiments, the sensor can be an electromagnetic waves based sensor, which sends electromagnetic waves towards the flexible airfoil, such as a LIDAR, a radar, a laser-based sensor, etc.;
- at least a load sensor, or at least two load sensors, such as (but not limited to) strain gauges, load cells, tension sensor, etc., for measuring the load of the suspension lines;
- if necessary, at least a sensor configured to sense data indicative of the geometrical configuration of the suspension lines of the air vehicle. An image sensor can be used, or an electromagnetic waves based sensor can be used, as mentioned above (such as a LIDAR). Depending on the embodiments, the same sensor can be used for sensing data indicative of the geometrical configuration of the suspension lines and of the airfoil, or different sensors can be used;
- at least a sensor for measuring general weather conditions, such as one or more sensors configured to measure temperature, pressure, wind velocity, wind direction, humidity;
- at least an inertial sensor for measuring inertial data of the air vehicle, such as (but not limited to) a velocity sensor, an acceleration sensor, a position sensor, an altitude sensor, a rate of descent sensor, etc.

The sensor configured to measure data indicative of the geometrical configuration of the flexible airfoil can be located at various positions, which include (but are not limited to) the head of the pilot, the helmet of the pilot, the suspension lines, the payload of the air vehicle, the automatic pilot unit of the air vehicle, the harness (for a manned air vehicle), the vehicle frame (such as a trike frame for powered air vehicles), etc.

These positions also apply to the sensor configured to sense data indicative of the geometrical configuration of the suspension lines.

Although **Fig. 4** depicts the sensor(s) **42** as being part of the system **40**, according to some embodiments, at least a subset of the sensor(s) **42** is not part of the safety system **40**. For example, this subset of sensor(s) **42** is part of the air vehicle.

The controller **41** can be connected to the sensor(s) **42** by an operator or in an automatic way. For example, the system **40** can detect electromagnetic waves sent by the sensor in order to be associated with said sensor. The connection between the controller **41** and said sensor(s) **42** can be a wired connection or can be wireless connection (such as through Bluetooth, Wifi, LTE, etc.).

As explained later in the specification, according to some embodiments, the controller **41** is configured to determine characteristics of local weather and can be further configured to command at least an actuator **44** for controlling the flight of the air vehicle.

The actuator **44** can be part of the system **40**. The actuator **44** can also be part of the air vehicle (that is to say that the actuator is an actuator which is already present in the air vehicle). According to some embodiments, a first subset of the actuators is part of the system **40** and a second subset of the actuators is part of the air vehicle.

The actuator **44** can include at least one of the following actuators:

- at least an alarm actuator configured to raise an alarm. The alarm actuator can include a sound speaker which provides an audio alarm. The alarm actuator can also include a visual screen which displays a visual alarm. The alarm actuator can also be connected to a remote central station (such as one of the emergency services) in order to send to said remote central station an alarm through any adapted communication network;
- an audio speaker providing steering commands to a pilot of the air vehicle;
- a screen for providing indications to the pilot (such as a micro-screen located on the goggles of the pilot);
- an actuator commanding the flight of the air vehicle, in particular an actuator which commands the steering of the air vehicle. According to some embodiments, the controller of the system **40** can send a control signal to at least an actuator which commands steering elements of the air

vehicle. This can include actuators which controls the wings of the air vehicle. In the case of a parachute, this can include part of the suspension lines. Indeed, as mentioned with respect to **Fig. 2**, according to some embodiments, at least part of the suspension lines allows controlling the steering of the air vehicle. According to some embodiments, the controller of the system can send a control signal to at least an actuator which commands the propulsion of the air vehicle (such as a motor embedded in the air vehicle).

According to some embodiments, the system comprises an interface (not represented) such as a screen associated to a keyboard (which includes at least one of a hardware keyboard and a software keyboard such as a tactile keyboard) which allows a user to interact with the system.

According to some embodiments, the interface is a dedicated interface for the system.

The interface can allow the user to enter various data on the air vehicle and/or the flight and/or the weather conditions, which can be stored in a storage of the system.

According to some embodiments, the interface is a pre-existing interface which communicates with the system. For example, a smartphone of the user can communicate with the system through a wired connection or a wireless connection. Thus, the smartphone plays the role of the interface with the system.

According to some embodiments, the system can comprise a communication unit (not represented) which allows wireless communication (such as, but not limited to, a radio emitter, an antenna emitter, etc.). In particular, this can allow the system to communicate information with other air vehicles or with a remote central station.

Referring now to **Fig. 5**, an embodiment of a method of measuring weather is described.

As shown in **Fig. 5**, the method can comprise a step **50** of sensing data comprising data indicative of the geometrical configuration of the flexible airfoil during operation of the air vehicle. In the present text, it is to be noted that the “operation” of the air vehicle can include various phases of the flight, on the ground and in the air.

In the case of a parachute, this can include the phase preceding the deployment of the canopy, the deployment of the canopy itself (on the ground or in the air), the flight, the landing, etc. This acquisition of data can be performed continuously during at

least part of the operation of the air vehicle, or can be repeated with a predefined frequency during at least part of the operation of the air vehicle. This acquisition of data can be performed by an appropriate sensor (as mentioned above with reference to **Fig. 4**) under the control of the controller **41** of the system **40**.

According to some embodiments, the step **50** comprises the step of taking an image with an image sensor (as mentioned with respect to **Fig. 4**), said image comprising the airfoil (and possibly a part of the environment surrounding the airfoil, which generally includes the sky).

The method can further comprise a step **50A** of extracting data indicative of the geometrical configuration of the airfoil from the sensed data. As mentioned later in the specification, this step can include for embodiment the use of an image processing algorithm.

The method can further comprise a step **51** of determining characteristics of local weather based at least on said extracted data. The step **51** can be performed e.g. by the controller **41** of the system **40** and/or by another controller (which can be embedded in the air vehicle or in a remote station communicating with the system **40**).

Step **51** can include determining characteristics of a turbulence encountered by the air vehicle during its operation.

Steps **50**, **50A** and **51** can be performed at several time points in order to follow the evolution of the characteristics of the airfoil during time, which reflect the characteristics of the local weather during time.

According to some embodiments, the characteristics of local weather are measured at low altitude (this is however not limitative), e.g. less than 200 feet.

If necessary, the controller can compare the characteristics of the local weather as calculated at step **51** to pre-stored reference values of the characteristics of the local weather which reflect different levels of turbulence. If this comparison shows that the level of turbulence implies a danger for the flight (for instance because the comparison differs from an operability criterion which defines the level of turbulence which can be supported by the air vehicle), the controller can perform an action, such as a safety action. If the level of the turbulence can be supported by the air vehicle, the controller can also perform flight actions to avoid the turbulence, such as by sending a control signal to flight actuators of the air vehicle.

As mentioned, the controller can calculate characteristics of the turbulence. The turbulence includes typically a local perturbation of the atmospheric conditions, which

induces a displacement of atmospheric particles with given dynamical and physical parameters (such as e.g. wind, gust, etc.).

Characteristics of the turbulence can include at least one of an amplitude, a frequency, a direction, and a volume (also called intensity) of a turbulence. The amplitude and the frequency of the turbulence can be defined, according to some embodiments, as the amplitude and the frequency of the velocity of the air in which the air vehicle is flying. According to some embodiments, the amplitude and the frequency of the turbulence can be defined and as the amplitude and the frequency of the velocity of the wind or gust in which the air vehicle is flying.

Similarly, the direction of the turbulence can be defined as the direction of the wind or gust in which the air vehicle is flying.

The volume or intensity of the turbulence can be measured based on the changes of amplitude of the turbulence during time (for example the amplitude varies from a first value to a second value in a given time interval), and on the frequency (which reflects how often these changes in amplitude versus time occur).

According to some examples, a grade is given to the amplitude and to the frequency (in a non limiting example this grade can comprise e.g. low, normal, moderate, severe, ultra-severe, etc.). A grade can also be given to the intensity based on the grade of the amplitude and frequency.

Since the airfoil is flexible, the evolution of the geometrical configuration of said airfoil reflects the turbulences in which the air vehicle is currently flying.

Characteristics of the local weather can also include the level of rain, which also influences the geometrical configuration of the airfoil and thus can be detected. In particular, a change in the behavior of the airfoil due to the absorption of water has a consequence on the distortion of the aerodynamic profile of the airfoil (which can be monitored by monitoring the form of the contour of the airfoil).

The profile of the airfoil can be monitored as explained with reference to **Fig. 5**, by monitoring the geometrical configuration of the airfoil during time. The presence of rain changes the shape of the airfoil so that flight speed of the air vehicle will be affected. In particular, flight speed will be higher than the normal flight speed.

According to some embodiments, the geometrical configuration of the airfoil is compared to a reference configuration. The reference configuration can reflect a normal operation of the airfoil, that is to say an operation of the airfoil under “normal” characteristics of local weather (which can be defined by the user or predefined in the

system). The “normal” characteristics of local weather can include a configuration without turbulence, or with low turbulence which does not have a significant impact on the configuration of the airfoil (the threshold can be defined by the user).

The evolution of the difference between the detected geometrical configuration and the reference configuration during time can reflect the characteristics of the local weather, and in particular of the turbulence.

The reference configuration can be retrieved from a storage of the system **40** (such as the storage **43** described in **Fig. 4**).

According to some examples, the reference configuration is a pre-stored reference configuration pertinent for at least said air vehicle.

According to some examples, the storage of the system stores a bank of reference configurations, each reference configuration being pertinent for an air vehicle or for a group of air vehicles.

The user can then enter in the system, through the interface, the model and/or the brand and/or the characteristics of the air vehicle so that the controller can extract the pertinent reference configuration.

As shown in **Fig. 6**, the reference configuration **62** can be obtained in different ways.

According to some examples, the reference configuration **62** is built based on a geometric analysis of the airfoil of the air vehicle (see block **60** in **Fig. 6**). This geometric analysis can be performed on a computer (such as in a laboratory) based on the knowledge of the air vehicle blueprints. This allows extracting the theoretical geometry that should be observed by the sensor(s) during the flight.

According to some examples, the reference configuration **62** is obtained during a real test (see block **61** in **Fig. 6**), such as during a trial flight.

A possible real test includes performing a trial flight of the air vehicle, during which the controller commands the sensor to acquire the reference configuration.

During the trial flight, it has to be indicated to the controller that the air vehicle is operating normally so that it can send a control signal to the sensor to acquire the reference configuration. The indication that the air vehicle is operating normally can be provided by the pilot of the air vehicle, through the interface of the system **40**, or by an external operator who monitors the flight and can communicate with the controller through an adapted communication unit.

According to some examples, the trial flight can be performed for each air vehicle. In this case, each time a user uses, for the first time, the system for an air vehicle, he has to perform the trial flight and to record the reference configuration during a normal operation.

According to other examples, a trial flight is performed for a given model of air vehicle (or groups of air vehicles), and the reference configuration is then stored in the storage of the system for this given model of air vehicle. In this case, a single trial flight (provided it is successful) is enough to obtain the reference configuration for this given model of air vehicle (or group of air vehicles).

According to some examples, the reference configuration **62** is obtained by performing a ground deployment of the air vehicle (see block **63** in **Fig. 6**), but without actual flying.

Fig. 7 illustrates the image of an airfoil **70** with a contour **71** which can be extracted from the data taken by the sensor configured for sensing data indicative of the geometrical configuration of said flexible airfoil. This configuration can be viewed as a reference configuration, that is to say under “normal” local weather (and without any malfunction of the airfoil).

This extraction can be based on an image processing algorithm such as an algorithm which detects edges in an image (“edge detection algorithm”). The algorithm can also take into account the colour of the edges of the canopy, which can be known in advance according to some embodiments.

According to some embodiments, the extraction of the contour can comprise applying an edge detector to the image sensed by the image sensor. Then, a filter can be used to remove noise (such as background noise from the sun, and presence of other edges such as the suspension lines). The method can then comprise starting from an outer contour that contains all the edges of the image and reducing the size of this contour toward the centre of the image until the first closed contour is reached, which is considered by the controller as the contour of the airfoil.

Other methods can be used to extract the contour of the airfoil.

When a turbulence occurs, the contour of the airfoil can be offset from its standard position. This is shown in the non limiting example of **Fig. 7A**.

According to some embodiments, the controller computes at least one of the relative location and relative angular position of the airfoil with respect to the sensor (the “normal” or reference position of the airfoil can be deduced e.g. from the reference

configuration which was mentioned with respect to **Fig. 6**, or from a knowledge of the position of the sensor with respect to the airfoil).

As shown in **Fig. 7A**, the main axes **76** of the airfoil are translated and tilted with respect to the main axes **75** of the sensor (see arrows **74** which represent the “offset” along each direction).

As shown in steps **77** and **78** of **Fig. 7B**, the controller can monitor the characteristics of the offset of the airfoil during time (such as the amplitude, frequency, variation in time, etc.) to calculate the characteristics of the local weather. As mentioned, the offset represents the relative displacement of the airfoil in the image due to the presence of the turbulence, with respect to a reference position or a reference configuration.

By monitoring the amplitude and the frequency of this offset (which reflects the dynamics of the evolution of the offset), the controller can calculate the amplitude and the frequency of the turbulence. Indeed, the amplitude of the variation of the offset, and the frequency of variation of said offset, are directly correlated to the amplitude and the frequency of the turbulence. A dynamic model of the airfoil, which reflects the deformation and displacements of the airfoil based on the mechanical input (here the turbulence) can be used to calculate the characteristics of the turbulence. This dynamic model can be computed in a laboratory based on analysis of the airfoil and/or based on true measurements.

According to some embodiments, the changes in the airfoil shape are counted in a predefined time frame. Similarly, the amplitude of these changes can be monitored in a predefined time frame. These data allow calculating the frequency and amplitude of the turbulence.

In addition, according to some embodiments, the direction of the turbulence can be calculated by monitoring the direction of the motion of the airfoil with respect to the payload.

For example (this example and the values are not limitative), if the airfoil moves two times in 1 second, this corresponds to a high frequency turbulence, whereas if the airfoil moves one time in 20 seconds this corresponds to a low frequency turbulence.

If the airfoil changes its position one meter to the left side and one meter back this indicates that the turbulence comes from the right direction. The level of the displacement (one meter) is generally considered as corresponding to a moderate turbulence.

If the airfoil collapses at the right side and the airfoil turns to the right side, this corresponds to a severe turbulence coming from the right side.

These examples are illustrative and various other analysis can be performed.

By monitoring the displacement of the airfoil with respect to its normal configuration (such as its rotation/translation), and/or with respect to the payload, the direction of the turbulence can also be calculated.

In particular, for a parachute, on ground, the canopy generally tends to align with the wind direction, which thus also provides an indication of the wind direction.

Fig. 8 shows a reference configuration **70** for the airfoil, which comprises a contour **71** (in dotted line) defining the contour of an airfoil in normal operation.

Fig. 8 also shows a comparison between a contour **80** of a flexible airfoil of an air vehicle in operation and the contour **71** of the reference configuration **70** of **Fig. 7**.

The contour **70** of the airfoil can be extracted from an image of the airfoil which is taken by an image sensor (see sensor **42** in **Fig. 4**) of the system **40**.

The controller of the safety system can then compare during time the extracted contour **80** with the contour **71** of the reference configuration **70**. This comparison can involve for embodiment a cross-correlation algorithm.

The comparison can yield an error (such as a cross-correlation error) indicating the level of discrepancies between the reference contour and the extracted contour.

By monitoring characteristics of the evolution of the error during time (e.g. but not limited to amplitude, frequency, position, direction...), the controller can calculate characteristics of local weather (amplitude, frequency, etc.) which is the source (in this example of **Fig. 8**) of the motion of the contour of the airfoil, and in particular in this example of the lateral side **81**. The calculation is similar to what was described with reference to **Figs. 7, 7A and 7B** but is now applied to a signal representing the error between the contour of the airfoil in normal local weather and the contour of the airfoil in operation.

The airfoil contour can change e.g. to the front, or back, in a symmetric way or in an asymmetric way (see e.g. **Fig. 7**). The airfoil contour can change as a result of collapses at one side or both sides at one time.

In the example of **Fig. 8**, during time, the position of the lateral side **81** will evolve due to the presence of the turbulence. This is shown by arrow **82** which illustrates the motion of the lateral side **81** during time due to the turbulence.

According to some embodiments, the contour of the airfoil (that is to say of the airfoil during operation of the air vehicle, and/or of a reference airfoil) can be extracted from data sensed by an electromagnetic waves based sensor, such as a radar or LIDAR, which measures the reflexion of electromagnetic waves on the airfoil. This type of sensor also provides an “image” of the airfoil (instead of pixels provided by the image sensor, a level of reflection of the waves is provided, which provides a map similar to a pixel-based image). Similar extracting methods can be used to extract the contour of the airfoil (these methods are applied to the aforementioned “image” of the airfoil). Similar analysis of the airfoil can be performed.

Both LIDAR and RADAR sensors measures the range of the reflecting object. A LIDAR can produce a cloud of points, where the azimuth, elevation and range of each point can be measured. The point cloud image looks similar to a camera image, except that the distance between the sensor and each point in the cloud is known. So, for example (this embodiment being non limitative), a processing unit can use the measurements of the LIDAR to build a 3D map of the airfoil based on the most remote points, and compare this map to a reference map of a fully functional airfoil (reference configuration).

Same or similar algorithms can be applied for RADAR outputs as well.

According to some embodiments, the evolution of the geometrical configuration of the airfoil is monitored to calculate the characteristics of the local weather, but is not necessarily compared to a reference configuration of the airfoil.

Indeed, according to some embodiments, the position of the airfoil during normal flight can be defined as belonging to a window within some boundaries. During the flight, the airfoil cannot fly out of this window. Indeed, out of this window, the airfoil will collapse.

According to some embodiments, this window can be predefined and the controller can measure the frequency at which the airfoil crosses the boundaries of the window or get close to these boundaries. The number of times the airfoil crosses the boundaries can be counted during a predefined time frame, and/or the range of the offset of the position of the canopy with respect to this window can be measured during a predefined time frame, so as to calculate characteristics of turbulence (frequency, amplitude, etc.).

Figs. 9 and 10 describe another possible embodiment of a method of measuring weather.

As shown in **Fig. 9**, visual markers **90** can be present on the airfoil. These visual markers **90** can be part of the structure of the airfoil (for instance they are particular logos or images that the maker of the air vehicle inserts on the airfoil at the manufacturing stage) and/or can be attached to the airfoil by adapted fastening tools. The visual markers **90** can be passive (such as - but not limited to - painted on the canopy, reflectors to electromagnetic waves such as radar waves or laser waves, etc.), or active (such as - but not limited to - LED lights, radio beacons, etc.). They can also be natural patterns of the airfoil.

The reference configuration of the airfoil can comprise an image representing the visual markers in an operation of the air vehicle under normal local weather. This reference configuration can be obtained as already explained with reference to **Fig. 6**.

Alternatively, or in addition, the reference configuration can also comprise a list of position of the visual markers relatively to the image (or relatively to the canopy) in a normal operation, and if necessary, the distance between the different visual markers in a normal operation.

As shown in **Fig. 10**, a method of measuring weather can comprise a step **100** of taking an image comprising the airfoil during operation of the air vehicle. The method can then comprise a step **100A** of extracting the visual markers from the image of the airfoil and calculating the position of the visual markers.

The evolution of the position of the extracted visual markers reflects the evolution of the geometrical configuration of the airfoil during time, which as mentioned reflects characteristics of local weather.

The controller can then determine characteristics of local weather (step **101** similar to steps **51** and **78**) and, if necessary, perform an action (step **102**).

According to some embodiments, the method can comprise comparing (at step **101**) the extracted position(s) of the visual markers with reference position(s) of the visual markers representing a normal operation of said airfoil or a corresponding airfoil (which corresponds to the "error"). The controller can then monitor the evolution of the error during time to determine the amplitude, frequency, of said error in order to calculate the characteristics of the turbulence, similarly to what was described with reference to steps **51** and **78**.

Figs. 10A, 11 and 12 describe another possible embodiment of a method of measuring weather.

As shown in **Fig. 10A**, the image used for building the reference configuration can comprise an airfoil **108** and a portion **109** of the sky.

As shown in **Fig. 11**, when the air vehicle is in a turbulence, at least part of the airfoil **110** can have a different form from the reference configuration, and this form can vary in time (see for example arrow **112** which shows that a border of the airfoil follows a back and forth movement, this illustration being not limitative). As a consequence, the portion **111** of the sky appearing in the image taken by the sensor changes accordingly (in particular, the proportion and/or the geometrical configuration of the sky appearing in the image changes in compliance with the dynamics of the turbulence in which the air vehicle is located).

By monitoring the evolution of the portion of the sky appearing in the image, the controller can determine characteristics of local weather, and in particular characteristics of turbulence, as already explained. As shown in **Fig. 12**, during operation of the air vehicle, the method of measuring weather can comprise the step **120** of extracting, from the images taken by the image sensor, a portion **111** of the image which comprises the sky.

The method can then comprise the step **121** of comparing the geometrical configuration of the extracted portion of the image comprising the sky, with a reference configuration of the sky appearing in an image comprising an airfoil without turbulence or with turbulence having an impact on the airfoil which is less than a predefined threshold (the difference between the two current portions of the sky and the reference portion of the sky being called the “error”).

This comparison can comprise at least one of:

- comparing the relative proportion of the sky in the image compared to a reference relative proportion;
- comparing the distribution of the sky in the image to a reference distribution (similarly to what was done for the airfoil itself, as explained with reference to **Fig. 8**). This comparison can comprise extracting the contour of the sky appearing in the image, and comparing this extracted contour with a reference contour representing a reference contour of the sky appearing in a reference image of a corresponding airfoil in operation without turbulence (or with low turbulence which does not have a significant impact on the configuration of the airfoil).

The extraction of the portion of the sky from the image taken by the image sensor can comprise for instance extracting pixels whose colour is in a predefined range (such as “blue”).

Alternatively, or in addition, the controller can use the images taken by the image sensor before the airfoil is opened, in order to learn the expected colour of the sky. Then, after the airfoil is opened, the portion of the sky can be extracted from the image by selecting the pixels which have the expected colour (for example with a colour histogram or with a filter or using a torch to light the airfoil).

By monitoring the evolution of the error (and in particular characteristics of said error such as, but not limited to, amplitude, frequency, etc.), the controller can then determine characteristics of local weather (step **122** – similar to steps **51**, **78** and **101**), and if necessary perform an action (step **123**). This action can comprise commanding at least an actuator of the air vehicle or of the system, based e.g. on the level of turbulence which was measured.

According to some embodiments the controller calculates the characteristics of local weather without comparing the extracted portion of the sky with a reference configuration (without performing step **121**). In this case, the controller monitors the evolution of the geometrical configuration of the extracted portion of the image comprising the sky (such as by monitoring the characteristics of a signal representing the proportion of the sky in the image during time, or by monitoring the characteristics of a signal representing the evolution of the contour of the sky in the image during time). Then, the controller calculates the characteristics of local weather based on the characteristics of the evolution of the geometrical configuration of the extracted portion of the image comprising the sky during time, similarly to what was described with reference to steps **51**, **78** and **101**.

Although the method of **Fig. 12** has been described with an image sensor, the portion of the sky can also be extracted from data acquired by an electromagnetic waves based sensor. Indeed, as already mentioned, this kind of sensor also provides an “image” of the airfoil and of the sky. The part of the image which does not reflect the electromagnetic waves sent by the sensor, or which reflect less said electromagnetic waves, or which has a distance with respect to the sensor which is greater than the normal distance between the airfoil and the sensor (a non limitative embodiment can be 30m or more instead of about 6m), can be considered as belonging to the sky.

Referring now to **Figs. 13** and **14**, another embodiment of a method of measuring weather is described.

In this method, and as shown in **Fig. 14**, at least a load sensor **141** is mounted on a suspension line **140** connected to the airfoil.

The method can comprise a step **130** of measuring the load of at least a suspension line using said load sensor.

The method can then comprise a step **141** in which the controller of the system analyzes the measured load.

This analysis can comprise extracting parameters from the signal representing the measured load, such as the frequency, the amplitude (in particular, maxima and minima at different points of time can be extracted), and the phase.

If necessary, the measured load can be compared to a reference load, which represents the normal load of this suspension line for normal characteristics of the weather (such as without turbulences, or with turbulences under a predefined threshold). In this case, the controller can monitor the characteristics of an error signal, which is the difference between the measured load and the reference load representing an operation of the airfoil in “normal” weather conditions (the normal weather conditions can be defined by the user, as already mentioned).

This reference load can be known in advance (e.g. by analysis), or can be measured during a trial flight of the air vehicle, which can be performed under normal local weather conditions. According to some embodiments, the user can also enter the weight of the payload (such as his own weight) through the interface of the system, so that the controller can calculate the reference load.

If the load of a plurality of suspension lines is measured, the controller can compare the measured load with a reference load for each suspension line.

The controller can then determine characteristics of local weather (step **132**), and in particular characteristics of turbulence such as amplitude, frequency, etc., based on the analysis of the characteristics of the load sensed on the suspension line, or on a plurality of suspension lines.

Similar analysis to what was described for steps **51**, **78**, **101** and **122** can be performed on the measured load to obtain the characteristics of local weather. Indeed, the presence of a turbulence induces a change of the load of the suspension lines. Evolution of the load (amplitude/frequency) during a predefined time period can be

monitored which provides in a similar way the amplitude and frequency of the turbulence.

If the load is measured on the right side of the airfoil and also on the left side of the airfoil, an analysis of the offset of the load between the right side and the left side can be performed during time. The measurement of the load at two sides of the airfoil can be used e.g. to detect if the change in the load is due to turbulence or to flight maneuvers performed by the air vehicle. It can also be used to detect the direction of the turbulence.

For example, if the frequency of the changes between the right side load and the left side load is two times in one second, the turbulence frequency can be considered as high, and if this frequency is one time every 20 seconds, the turbulence frequency can be considered as low.

If the offset between the load on a right side suspension line and a left side suspension line is 10 kg, this can be considered as a low turbulence. If the offset between the load on a right side suspension line and a left side suspension line is 20 kg, this can be considered as a moderate turbulence.

For example, if the offset in the load (such as between the right side and the left side of the airfoil, or between the measured load and a reference value of the load) holds for 0.5 seconds, the amplitude of the turbulence can be considered as low and if it is continually for 2-3 seconds it can be considered as a moderate amplitude.

These examples are illustrative and various other analysis can be performed.

The measurement of the direction of the turbulence can comprise detecting if the changes in the load are symmetric between a load sensor mounted on a suspension line connected to the right side of the airfoil and a load sensor mounted on a suspension line connected to the left side of the airfoil.

According to some embodiments, the controller can detect which of the load sensor measures first a change in the load, which can indicate that the turbulence is oriented towards the side on which this load sensor is present. The controller can also detect, after a time interval, if these changes in the load are also measured on the load sensor present on the other side of the airfoil. This can allow the controller measuring the direction of the turbulence.

According to some embodiments, the presence of the turbulence tends to move the airfoil from its normal position. For example, the airfoil can be pulled sideward or backwards, and the direction of the motion of the airfoil depends notably on the direction of the turbulence. The change of the position of the airfoil induces a change

of the load measured by the load sensors. Thus, it is possible to detect the direction of the turbulence based on the load measured by the load sensors. For example, it is possible to store a model or rules for the load which reflect for each possible direction of turbulence, the corresponding expected distribution of the load.

A non limitative example is depicted in **Fig. 15**. In this Figure, curve **150** represents the evolution of the velocity of a turbulence during time at a given location. Curve **151** represents the load measured on a suspension line. As shown, curve **150** is the envelope of the maxima of curve **151**, and thus can be used to calculate the characteristics of the turbulence.

According to some embodiments, if the variation between the maximal and minimal amplitudes (references **152** and **153**) of curve **151** with respect to time does not meet an operability criterion (such as if the comparison shows it is above a threshold), the controller can detect that this turbulence is incompatible with a normal flight (this can be used e.g. to perform an action such as a safety action). If necessary, according to some embodiments, the turbulences can be classified into different levels.

According to some examples, the load is measured on a plurality of suspension lines. In this case, the controller can perform an analysis of the load measured on each suspension line, and calculate the characteristics of local weather based on each measured load. It can then for example (this example being non limitative) calculate an average of the characteristics calculated based on the measurement of each suspension line, in order to improve the precision. Other aggregations or comparisons can be performed.

Fig. 16 describes the building of a weather database based on the measurements described previously. This weather database can be for example stored in a memory of the system **40**, or stored in a remote central station, or communicated to other air vehicles through a communication unit.

During operation of the air vehicle comprising a flexible airfoil, and as described previously, it is possible to calculate characteristics of local weather at various locations and various altitudes.

These data can be used to build a weather database.

The weather database can comprise for a plurality of locations and altitudes, characteristics of local weather/turbulence that were calculated according to the methods described previously. According to some embodiments, the turbulences are

classified in the weather database into a plurality of intensity levels depending e.g. on their amplitude/frequency. For example, the intensity levels can be divided into low intensity, medium intensity and high intensity, depending on the impact that they can produce on an air vehicle in operation. Other classifications can be used.

The weather database can further comprise, for each of a plurality of locations, data indicative of the nature of the ground at said location.

Data indicative of the nature of the ground can include data indicative of the topography of the ground at these locations, which reflect the altitude of the elements present on the ground, and thus the presence of slopes, mountains, valleys, etc.

The data indicative of the nature of the ground can also include the colour of the ground (which influence the heat reflectivity level of the ground), the temperature level of the ground, etc.

The weather database can further comprise data indicative of the general weather conditions, which indicate under which general weather conditions the characteristics of local weather were measured by the air vehicle. The data indicative of the general weather conditions can include e.g. (but is not limited to) the season (summer, winter, etc.), the position of the sun, the general direction of the wind, etc.

It is to be noted that this is not mandatory, and according to some embodiments, the weather database stores for at least some locations, only data indicative of the nature of the ground (e.g. for cases in which the turbulence that was measured at these locations does not depend on the general weather conditions, but mainly on the nature of the ground).

According to some embodiments, it is intended to find a correlation between the characteristics of the local weather as measured by the air vehicle and either the data reflecting the nature of the ground, or the data reflecting the general weather conditions, or both. According to some embodiments, this correlation is found for turbulences measured at an altitude inferior to 200 feet from the ground (this value being not limitative).

For example, as shown in **Fig. 17**, a turbulence **171** with given characteristics was measured at the location and altitude depicted in **Fig. 17**.

In the weather database, it appears that at this location on the ground, a mountain **170** is present.

In addition, in the weather database, the general weather conditions indicate that the wind had a direction as illustrated by arrow **173**.

It thus appears that the presence of the mountain, together with the particular direction of the wind as illustrated by arrow **173**, are correlated to the presence of a turbulence with the intensity measured by the system at this location and altitude.

If the wind has another direction (such as the direction represented by arrow **172**), it is expected that a turbulence with the intensity of turbulence **171** will not be measured at this location.

Another example is provided in **Fig. 18**. A turbulence **181** with a given intensity was measured at the location and altitude depicted in **Fig. 18**.

In the weather database, it appears that at this location on the ground, a slope **180** is present.

In addition, in the weather database, the general weather conditions indicate that the sun had a position which faces the slope.

It thus appears that the presence of the slope, together with the particular position of the sun, are correlated to the presence of a turbulence with the intensity measured by the system at this location and altitude.

According to some embodiments, the colour of the slope which indicates the dryness of the ground (colour which tends to a black colour) can be correlated to the fact that a turbulence is present at this location. Indeed, a portion of ground which has a dark colour tends to heat up the air which creates thermal conditions that can create vertical turbulence.

Fig. 19 shows a possible method of building a weather database which correlates the characteristics of local weather as measured to various data.

In this embodiment, a controller operable on a processing unit (which can be the controller of an air vehicle or another remote controller) correlates characteristics of the local weather as measured by the system at a plurality of locations (or a level of intensity representing the characteristics of the local weather), with data indicative of nature of the ground at said locations, such as data indicative of the ground topography at said locations (step **190**).

A cross-correlation with data indicative of the dryness of the ground (which is reflected by the colour of the ground) can be also performed, and a cross-correlation with other data reflecting the nature of the ground can be performed.

According to some embodiments, a cross-correlation between the distribution of the level of turbulences at a plurality of locations and data indicative of the ground topography at said locations is performed.

An index reflecting the level of correlation between said data can be output. If the index is above a threshold at a location for which a turbulence was measured, this can indicate that the ground topography at this location is correlated to the presence of the turbulence.

The weather database can store said index, or store an information (such as a pointer, or any adapted representation) which reflects the fact that the ground topography at this location is correlated to the presence of the turbulence (step 191).

According to some embodiments, the weather database can also store for each location the characteristics of the turbulence and only the data indicative of the nature of the ground which are correlated to said turbulence. For example, if the controller has detected that the topography of the ground at a particular location is correlated to the presence of the turbulence, but that other data indicative of the nature of the ground (such as the dryness of the ground) are not correlated to the presence of the turbulence, the weather database can store for this location only the characteristics of the turbulence and the corresponding topography of the ground at said location.

In addition, this index or information can be stored in the weather database for given general weather conditions which are also stored in the weather database.

Thus, this index or information which express the correlation between the nature of the ground and the presence of the turbulence can be stored as being valid only for said general weather conditions, or for a subset of said general weather conditions.

Rules can be set for defining the general weather conditions that need to be stored in the weather database because these general weather conditions are pertinent for explaining the presence of the turbulence (these rules can be stored e.g. in a memory communicating with the controller). These rules can be computed based on general meteorological rules, and on a general knowledge of the sources of turbulences.

For example, in the summer, the location of the sun is a parameter that needs generally to be stored, since it can influence the presence of the turbulence.

Similarly, the temperature and humidity rate can be correlated to the presence and to the strength of the turbulence.

The direction of the wind is also a typical data which influences the presence of the turbulence. Other rules can be set depending on the needs, the locations, the *a priori* knowledge of the sources that can cause turbulences, etc. As mentioned, these rules can be stored in a memory so that the controller can automatically extract the

pertinent general weather conditions that need to be stored in the weather database for the locations where a turbulence was measured by the air vehicle.

As a consequence, the weather database can store characteristics of local weather (such as level of turbulence, amplitude, etc.) and also a list of data which are correlated to the presence of said turbulence.

Based on this weather database, a determination and analysis of the characteristics of local weather can be made. This determination can comprise an *a priori* determination of the characteristics of local weather (prediction) and/or a determination of the characteristics of local weather during operation, such as of an air vehicle (such as a real time determination/analysis).

Fig. 19A illustrates a non limitative example of a correlation between the ground topography at various locations (the X axis represents a direction on the ground, and the H axis represents the height of the ground), and the amplitude of the turbulence measured by the air vehicle at said locations (the I axis represents the amplitude of the turbulence).

Reference **193** in the upper curve indicates the presence of a mountain. Reference **194** in the lower curve indicates the presence of a turbulence.

When the controller correlates (such as by performing a cross-correlation) the two curves, it appears that the presence of the turbulence is correlated to the presence of the mountain. Thus, the controller can store in the weather database an information which indicates that the turbulence is correlated to the presence of a mountain with the height H1 (see **Fig. 19A**). According to some embodiments, it can also store information on general weather conditions for which the turbulence was measured (such as wind direction, etc.).

Embodiments of methods of determining weather based on the weather database are illustrated in **Figs. 20 to 22**.

According to some embodiments, the methods can be performed by at least a controller operable on a processing unit, which can be for example on ground or located in an air vehicle (which is not necessary an air vehicle with a flexible airfoil). The controller can be operable to communicate with the weather database, which can be stored in a non-transitory memory located e.g. on ground or in an air vehicle. The controller and the weather database can belong to a system for determining weather (not represented).

A first embodiment of a method of determining (during operation, which can be real time, or by performing an *a priori* prediction) the characteristics of local weather (such as turbulence) at a given location is depicted in this figure. The characteristics include e.g. as mentioned amplitude, frequency, direction, etc. and/or an intensity level characterizing the intensity of the turbulence.

In this embodiment, the given location is already present in the weather database, that is to say that the air vehicle with a flexible airfoil (such as the air vehicle of **Figs. 1 to 3**) has already been in operation at this location to measure characteristics of local weather.

At another period of time, it is now desired to determine the characteristics of local weather at this given location, for example to plan a new flight path, or to correct a current flight path.

In this case, the method can comprise a step **200** of receiving data on the general weather conditions at said given location. Depending on the types of the data, said data can be provided by sensors which are located at said given location, or by specialized operators which provide information on the weather, or by ephemerides.

For example, these data can comprise information on the position of the sun, information on the general wind direction, etc.

The method can then comprise a step **201** of comparing general weather conditions at this given location with general weather conditions stored in the weather database for this given location. If this comparison complies with a matching criterion (which can be predefined or defined by the user), this indicates that the characteristics of local weather (such as turbulence) which were measured for this location and stored in the weather database are expected to be present at said location (prediction step **202**).

As a non limiting example, as shown in **Fig. 17**, this can comprise comparing the general wind direction measured at said location with the general wind direction stored in the weather database (which is represented by arrow **173**). If these directions match, the method can predict that a turbulence with the characteristics of the turbulence **171** is expected to be present at said location.

If this comparison does not comply with a matching criterion, this indicates that the characteristics of local weather which were measured for this location and stored in the weather database are not expected to be present at said location.

A second embodiment of a method of determining the characteristics of local weather (such as turbulence) at a given location “X” is depicted in **Fig. 21**.

In this embodiment, the characteristics of the local weather (such as turbulence) for the given location “X” are not present in the weather database. However, data indicative of the nature of the ground (such as the topography) at said given location are known. In addition, if required, data on the general weather conditions at said given location are known.

The method can comprise a step **210** of receiving or providing data on the nature of the ground at said given location “X”.

The method can then comprise a step **211** of searching in the weather database for at least another location “Y” with similar ground data.

As a non limitative example, the given location can have a slope. The method can comprise searching in the weather database for another location “Y” with a similar slope.

The method can then comprise a step **212** of extracting from the weather database the characteristics of local weather stored for this another location “Y”.

Since said another location “Y” has for example a topography which is similar to the topography of the given location “X” for which the characteristics of the local weather are sought, it is expected that the characteristics of the local weather at said another location “Y” will be similar to the characteristics of the local weather at this given location “X”.

The extracted characteristics can then be output to the user or transmitted to any other system which requires said information (for example a system which plans the flight path of air vehicles, or to another air vehicle).

If necessary and illustrated in steps **220** to **222** of **Fig. 22**, the method can also comprise comparing the general weather conditions at the given location “X” with the general weather conditions at said another location “Y” (which was identified as also having similar data indicative of the nature of the ground).

If this comparison complies with a matching criterion, the method can then predict that the characteristics of local weather stored for said another location “Y” will be present at said given location “X”.

Thus, various analysis of local weather can be performed, which can be useful for various applications, such as the planning and/or the control in operation of a flight path of an air vehicle.

Fig. 23 illustrates a method of planning the flight path of an air vehicle (which is not necessary an air vehicle with a flexible airfoil). According to some embodiments, the method can be performed by at least a controller operable on a processing unit, which can be for example on ground or located in an air vehicle. The controller can be operable to communicate with the weather database, which can be stored in a non-transitory memory located e.g. on ground or in an air vehicle. The controller and the weather database can belong to a common system, such as a system for determining the flight path of an air vehicle (not represented).

The method can comprise a step **230** of determining characteristics of local weather on a flight path of the air vehicle, based on the weather database. In particular, as mentioned in the embodiments of **Figs. 20 to 22**, data indicative of the nature of the ground on said flight path and, if necessary, data reflecting general weather conditions on said flight path can be used to determine the characteristics of local weather on the flight path of the air vehicle.

Depending on the determination (in real time or using an *a priori* analysis such as before the flight of the air vehicle) of the characteristics of local weather that were computed at step **230**, the flight path can be recalculated and/or changed based on said determination (step **231**).

For example, if turbulences are expected on the flight path with a level which is not compliant with the requirements of the mission of the air vehicle, the flight path can be recalculated to avoid said turbulences. For example, the flight path can be recalculated so that the air vehicle flies outside the location in which the turbulences are expected to be present.

According to some embodiments, the method of **Fig. 23** is performed during operation of an air vehicle in order to recalculate the flight path of the air vehicle e.g. to avoid turbulence.

According to some embodiments, if it is detected that a turbulence has a level (for example in terms of amplitude, or in terms of amplitude with respect to time, or in terms of frequency) which is above a security level, the controller of the system can perform a safety action.

According to some embodiments, the controller can raise an alarm, such as an audio alarm, to the pilot of the air vehicle. The alarm can also be a vibration provoked by an actuator which causes a vibration felt by the pilot. The alarm can also be a

visual alarm. The alarm can also be communicated remotely to emergency services. Other types of alarms can be raised.

Other safety actions can be performed if necessary.

According to some embodiments, the controller can provide steering commands to a pilot of the air vehicle, such as audio steering commands. According to some embodiments, the controller can provide steering commands to an automatic pilot unit controlling the flight actuators of the air vehicle.

For example, the controller can provide steering commands which lead the air vehicle to fly towards a safer zone, such as a zone outside the zone where the turbulence is present.

According to some embodiments, if the controller detects the presence of turbulences before the takeoff of the air vehicle, it can perform a safety action for aborting takeoff. The safety action can comprise indicating to the pilot that the takeoff has to be aborted. Alternatively, the controller can control the automatic pilot unit which controls the flight actuators of the air vehicle, for aborting takeoff. The automatic pilot unit can for example cause the canopy to collapse in the case of a parachute, or can stop the motor of the parachute, etc.

According to some embodiments, the controller performs a sequence of safety actions. A possible sequence can include the following steps. If a turbulence has been detected, the controller first raises an alarm. After a given time, if the controller monitors that the turbulence has not stopped, it indicates to the pilot steering commands to be performed or sends commands to an automatic pilot unit for performing said steering commands. After a given time, if the controller monitors that the turbulence has not stopped, it can perform any adapted safety action (such as emergency landing).

The invention contemplates a computer program being readable by a computer for executing one or more methods of the invention. The invention further contemplates a machine-readable memory tangibly embodying a program of instructions executable by the machine for executing one or more methods of the invention.

It is to be noted that the various features described in the various embodiments may be combined according to all possible technical combinations.

It is to be understood that the invention is not limited in its application to the details set forth in the description contained herein or illustrated in the drawings. The

invention is capable of other embodiments and of being practiced and carried out in various ways. Hence, it is to be understood that the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting. As such, those skilled in the art will appreciate that the conception upon which this disclosure is based may readily be utilized as a basis for designing other structures, methods, and systems for carrying out the several purposes of the presently disclosed subject matter.

Those skilled in the art will readily appreciate that various modifications and changes can be applied to the embodiments of the invention as hereinbefore described without departing from its scope, defined in and by the appended claims.

CLAIMS

1. A system for the measurement of weather, comprising:
 - at least a sensor configured to sense data comprising data indicative of the geometrical configuration of a flexible airfoil of an air vehicle, and
 - at least a controller configured to:
 - o extract data indicative of the geometrical configuration of the airfoil in operation from the sensed data, and
 - o determine characteristics of local weather based at least on said extracted data.
2. A system for the measurement of weather, comprising:
 - at least a load sensor mounted on at least a suspension line attached to a flexible airfoil of an air vehicle, for measuring the load of the suspension line, and
 - at least a controller configured to determine characteristics of local weather based at least on the load measured on the suspension line of the air vehicle in operation.
3. The system of any of claims 1 or 2, wherein the characteristics of local weather comprise at least one of an amplitude, a frequency, a direction, and a volume of a turbulence.
4. The system of any of claims 1 and 3 wherein the controller is configured to determine characteristics of the dynamics of the geometrical configuration of the airfoil during operation of the air vehicle in order to determine characteristics of the local weather.
5. The system of any of claims 2 and 3 wherein the controller is configured to determine characteristics of the dynamics of the load of the suspension line during operation of the air vehicle in order to determine characteristics of the local weather.
6. The system of any of claims 1, 3 and 4 wherein the controller is configured to compare at least part of the extracted data with at least a reference configuration representing an operation of the airfoil under normal weather conditions, and to determine characteristics of the local weather based at least on said comparison.

7. The system of any of claims 1, 3, 4 and 6 wherein the controller is configured to determine an offset of the airfoil and/or a deformation of the airfoil, and to calculate the characteristics of the local weather based on said determination.
8. The system of any of claims 1 to 7, wherein the controller is configured to determine characteristics of local weather during operation of the air vehicle on the ground and/or in the air.
9. The system of any of claims 1, 3, 4 to 8, wherein the sensor comprises at least one of an image sensor and an electromagnetic waves based sensor configured to measure data indicative of the geometrical configuration of the airfoil based on the emission of electromagnetic waves towards the airfoil.
10. The system of any of claims 1 to 9, wherein the controller is configured to build a weather database based on said determination of the characteristics of the local weather at a plurality of locations.
11. The system of claim 10, wherein the weather database comprises, for each of a plurality of locations, characteristics of local weather and data indicative of the nature of the ground at said location.
12. The system of claim 10, wherein the weather database comprises, for each of a plurality of locations, characteristics of a turbulence measured by the system, data indicative of the ground topography at said location and data indicative of general weather conditions.
13. The system of any of claims 1 to 12, wherein the controller is configured to build a weather database which correlates characteristics of the local weather as measured by the system at a plurality of locations, with data indicative of the nature of the ground at said locations and/or data indicative of general weather conditions at said locations.
14. The system of claim 13, wherein the controller is configured to determine, based at least on said weather database, characteristics of local weather at a given location.
15. The system of claim 14, wherein this determination is performed even if said given location is not part of the database, wherein the controller is configured to determine characteristics of local weather at said given location based on said weather database, data indicative of the nature of the ground at said given location and/or data indicative of general weather conditions at said given location.

16. The system of any of claims 1 to 15, further comprising a communication unit for transmitting characteristics of local weather as measured to other air vehicles.
17. The system of any of claims 1 to 16, wherein the controller is configured to control at least an actuator for controlling the flight of the air vehicle based on the characteristics of local weather calculated by the system.
18. An air vehicle comprising a flexible airfoil, at least a suspension line attached to said airfoil and a system for the measurement of weather according to any of claims 1 to 17.
19. A computer-implemented controller operatively coupled to at least a sensor configured to sense data comprising data indicative of the geometrical configuration of a flexible airfoil of an air vehicle, the controller being configured to extract data indicative of the geometrical configuration of the airfoil in operation from the sensed data, and determine characteristics of local weather based at least on said extracted data.
20. A computer-implemented controller operatively coupled to at least a load sensor mounted on at least a suspension line attached to a flexible airfoil of an air vehicle, the controller being configured to determine characteristics of local weather based at least on the load measured on the suspension line of the air vehicle in operation.
21. A weather database comprising:
 - characteristics of local weather for a plurality of locations;
 - data indicative of the nature of the ground at said plurality of locations,

wherein the weather database comprises information on a correlation between the data indicative of the nature of the ground at said plurality of locations and characteristics of the local weather at said plurality of locations.

22. The weather database of claim 21 further comprising data indicative of general weather conditions at said plurality of locations.
23. The weather database of claim 21, wherein the characteristics of local weather comprise at least one of an amplitude, a frequency, a direction, and a volume of a turbulence.
24. A system for determining weather, the system comprising a controller configured to determine characteristics of local weather at a plurality of locations based at least on the weather database according to claim 21 and data indicative of the nature of the ground at said locations.

25. The system of claim 24, wherein the controller is configured to, for a given location with given data indicating the nature of the ground at said given location,

- search in the weather database at least another location for which the data indicating the nature of the ground at said another location match said given data indicating the nature of the ground at said given location, and
- extract the characteristics of the local weather at said location from the weather database to determine the local weather at said another location.

26. The system of claim 24, wherein the controller is configured to, for a given location with given data indicating the nature of the ground at said given location and given general weather conditions:

- search in the weather database at least another location for which
 - the data indicating the nature of the ground at said another location match said given data indicating the nature of the ground at said given location according to a matching criterion, and
 - the given general weather conditions stored in the weather database for said another location match the general weather conditions stored in the database at said given location according to a matching criterion;
- extract the characteristics of the local weather at said another location from the weather database to determine the local weather at said given location.

27. A method of measuring weather, comprising:

- sensing data comprising data indicative of the geometrical configuration of a flexible airfoil of an air vehicle with at least a sensor,
- extracting data indicative of the geometrical configuration of the airfoil in operation from the sensed data, and
- determining characteristics of local weather based at least on said extracted data.

28. A method of measuring weather, comprising:

- sensing load of at least a suspension line attached to a flexible airfoil of an air vehicle, with at least a load sensor, and

- determining characteristics of local weather based at least on the load measured on the suspension line of the air vehicle in operation.
29. The method of any of claims 24 or 25, wherein the characteristics of local weather comprise at least one of an amplitude, a frequency, a direction, and a volume of a turbulence.
30. The method of any of claims 24 and 26 comprising determining characteristics of the dynamics of the geometrical configuration of the airfoil during operation of the air vehicle in order to determine characteristics of the local weather.
31. The method of any of claims 25 and 26 comprising determining characteristics of the dynamics of the load of the suspension line during operation of the air vehicle in order to determine characteristics of the local weather.
32. The method of any of claims 24, 26 and 27 comprising comparing at least part of the extracted data with at least a reference configuration representing a normal operation of the airfoil, and determining characteristics of the local weather based at least on said comparison.
33. The method of any of claims 24, 26, 27 and 29 comprising determining an offset of the airfoil and/or a deformation of the airfoil, and calculating the characteristics of the local weather based on said determination.
34. The method of any of claims 24 to 30, comprising determining characteristics of local weather during operation of the air vehicle on the ground and/or in the air.
35. The method of any of claims 24 to 31, comprising building a weather database based on said determination of the characteristics of the local weather at a plurality of locations.
36. The method of claim 32, wherein the weather database comprises, for each of a plurality of locations, characteristics of local weather and data indicative of the nature of the ground at said location.
37. The method of claim 32, wherein the weather database comprises, for each of a plurality of locations, characteristics of a turbulence, data indicative of the ground topography at said location and data indicative of general weather conditions.
38. The method of any of claims 24 to 34, comprising building a weather database which correlates characteristics of the local weather as measured by the system at

- a plurality of locations, with data indicative of the ground topography at said locations and/or data indicative of general weather conditions at said locations.
39. The method of claim 35, comprising determining, based on said weather database, characteristics of local weather at a given location.
40. The method of claim 36, wherein this determination is performed even if said given location is not part of the weather database, and comprises determining characteristics of local weather at said given location based on said weather database, data indicative of the nature of the ground at said given location and/or data indicative of general weather conditions at said given location.
41. The method of any of claims 24 to 37, further comprising transmitting characteristics of local weather as measured to other air vehicles.
42. The method of any of claims 24 to 37, further comprising controlling at least an actuator for controlling the flight of the air vehicle based on the characteristics of local weather calculated by the system.
43. A method of building a weather database, comprising storing characteristics of local weather for a plurality of locations, data indicative of the nature of the ground at said plurality of locations, and information on a correlation between the data indicative of the nature of the ground at said plurality of locations and characteristics of the local weather at said plurality of locations.
44. The method of claim 43, comprising storing data indicative of general weather conditions at said plurality of locations in the weather database.
45. A method of determining weather, comprising:
- determining characteristics of local weather at a plurality of locations based at least on the weather database according to claim 21 and data indicative of the nature of the ground at said locations.
46. The method of claim 45, comprising, for a given location with given data indicating the nature of the ground at said given location:
- searching in the weather database for at least another location for which the data indicative of the nature of the ground at said another location match said given data indicative of the nature of the ground at said given location, and
 - extracting the characteristics of the local weather at said location from the weather database to determine the local weather at said another location.

47. The method of claim 45, comprising, for a given location with given data indicating the nature of the ground at said given location and given general weather conditions:

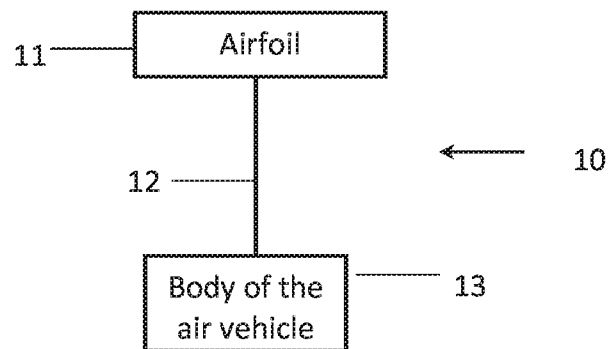
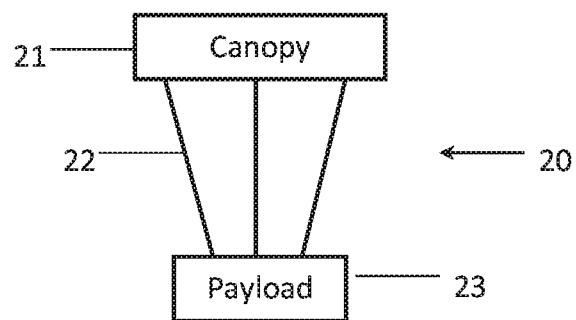
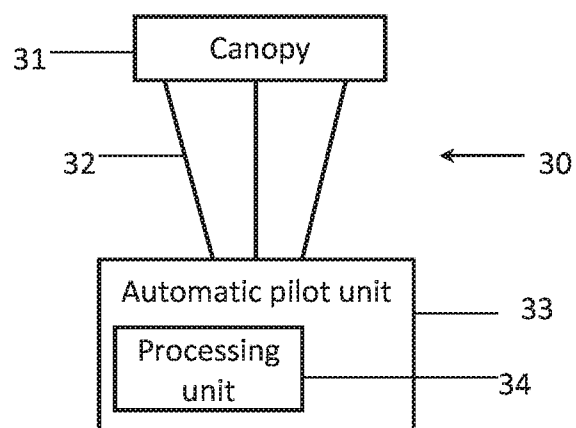
- searching in the weather database for at least another location for which
 - o the data indicative of the nature of the ground at said another location match said given data indicative of the nature of the ground at said given location according to a matching criterion, and
 - o the given general weather conditions stored in the weather database for said another location match the general weather conditions stored in the database at said given location according to a matching criterion, and
- extracting the characteristics of the local weather at said another location from the weather database to determine the local weather at said given location.

48. A method of planning the flight path of an air vehicle, comprising:

- determining characteristics of local weather on a flight path of the air vehicle, based on the weather database of claim 21 and data indicative of the nature of the ground on said flight path, and
- planning the flight path based on said determination.

49. A non-transitory storage device readable by a machine, tangibly embodying a program of instructions executable by the machine to perform a method according to claims 27 to 48.

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**Fig. 1****Fig. 2****Fig. 3**

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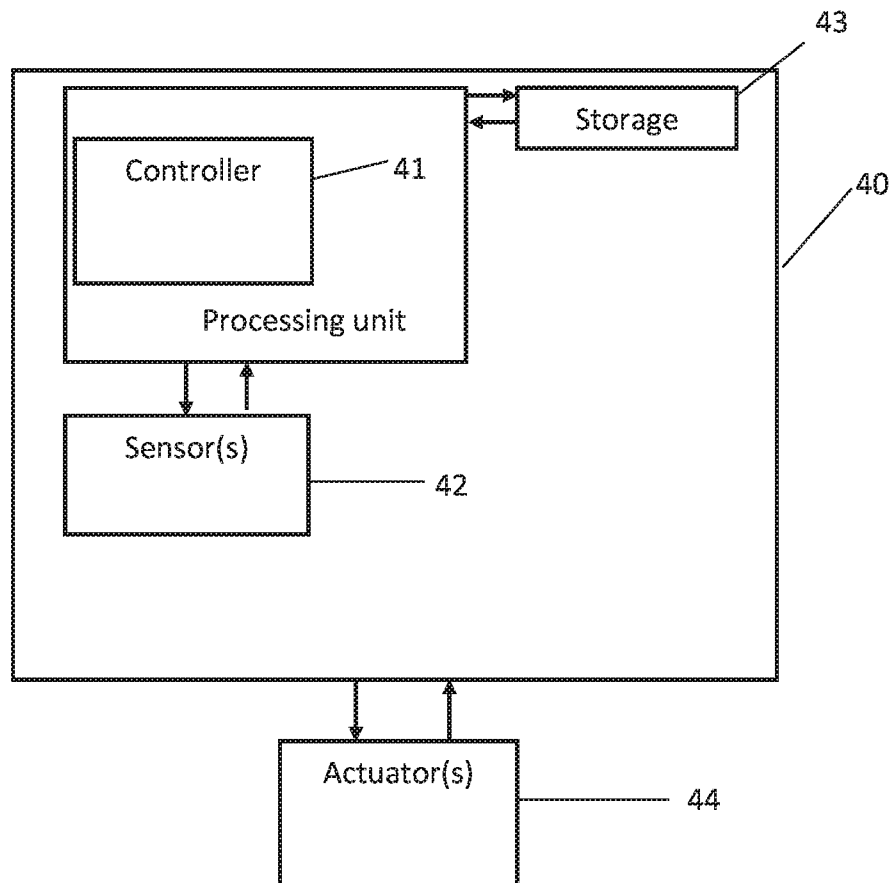


Fig. 4

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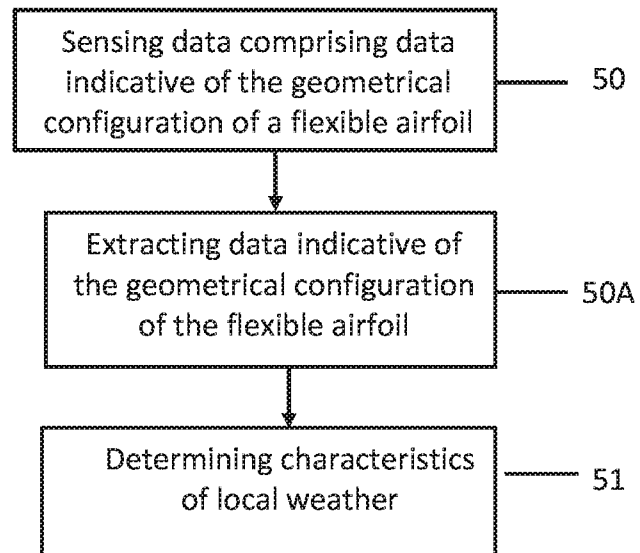


Fig. 5

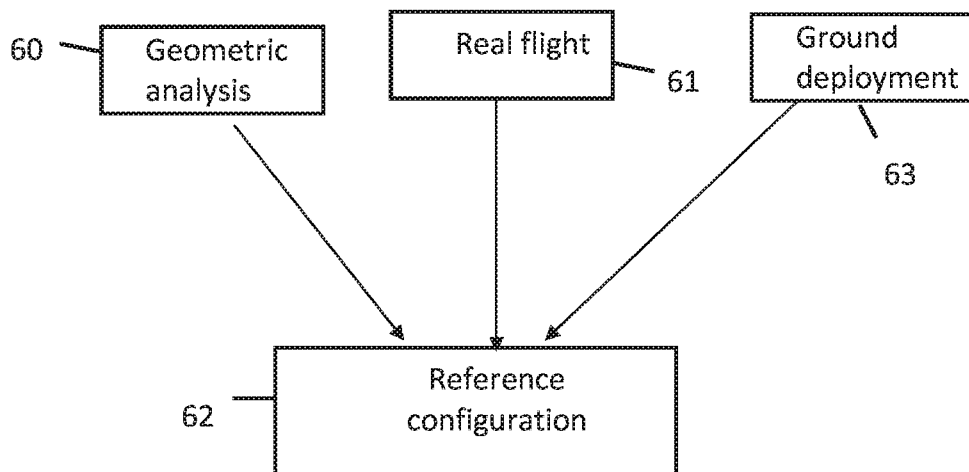


Fig. 6

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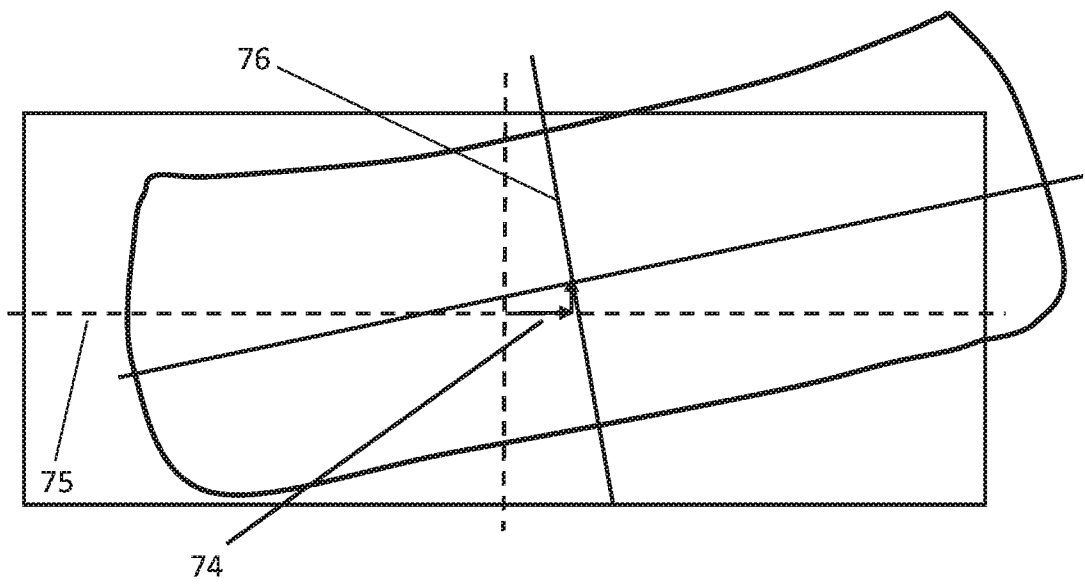
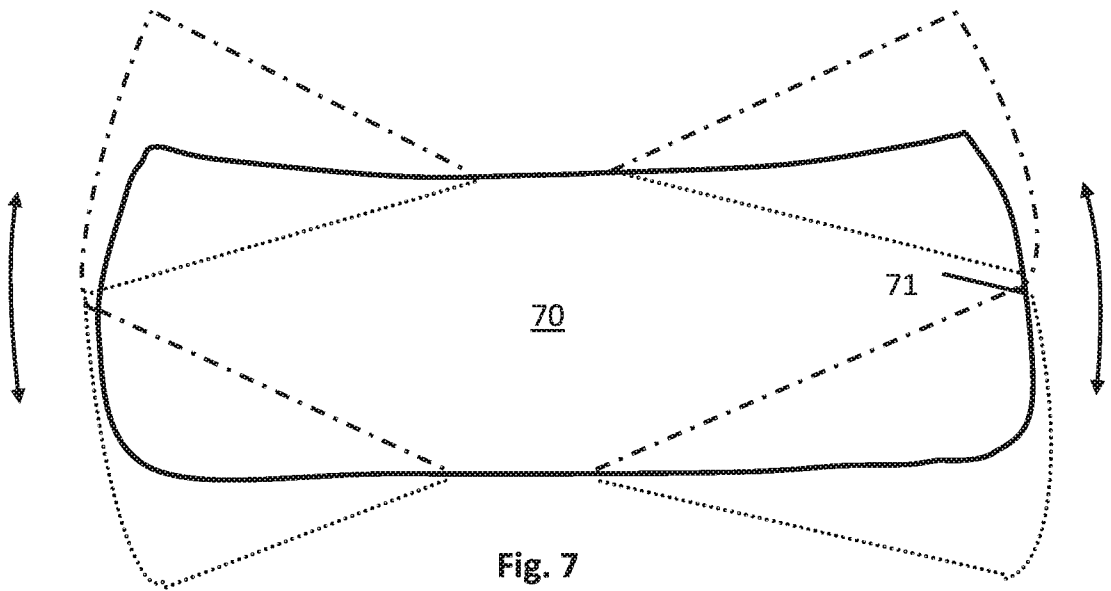


Fig. 7A

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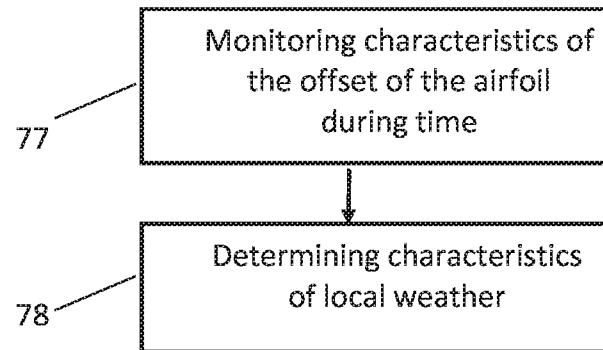


Fig .7B

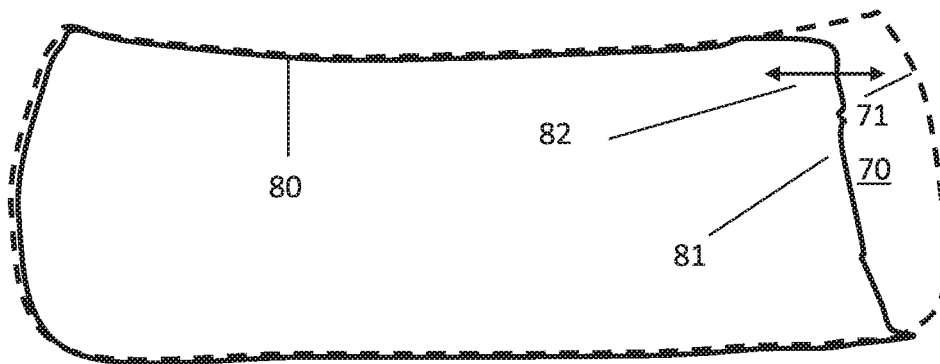


Fig. 8

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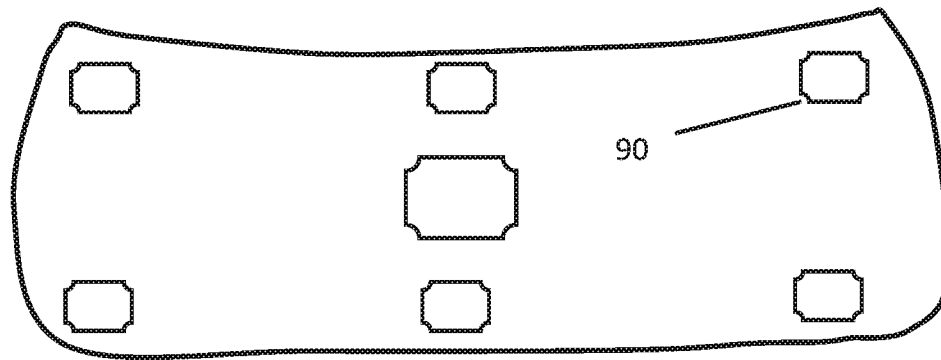


Fig. 9

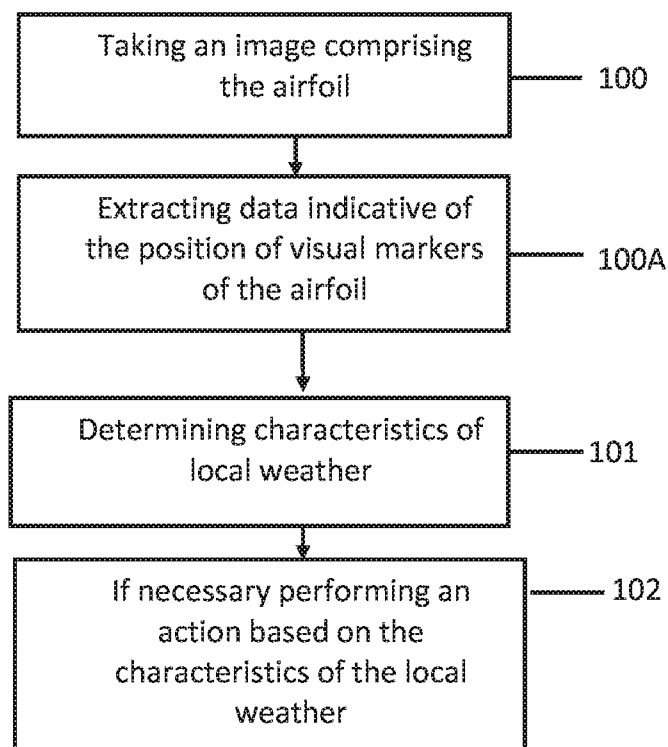


Fig. 10

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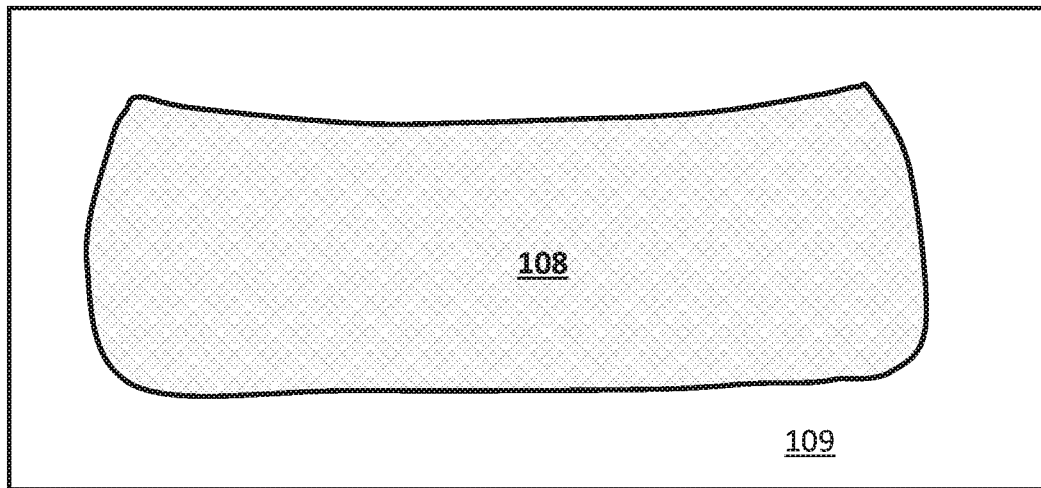


Fig. 10A

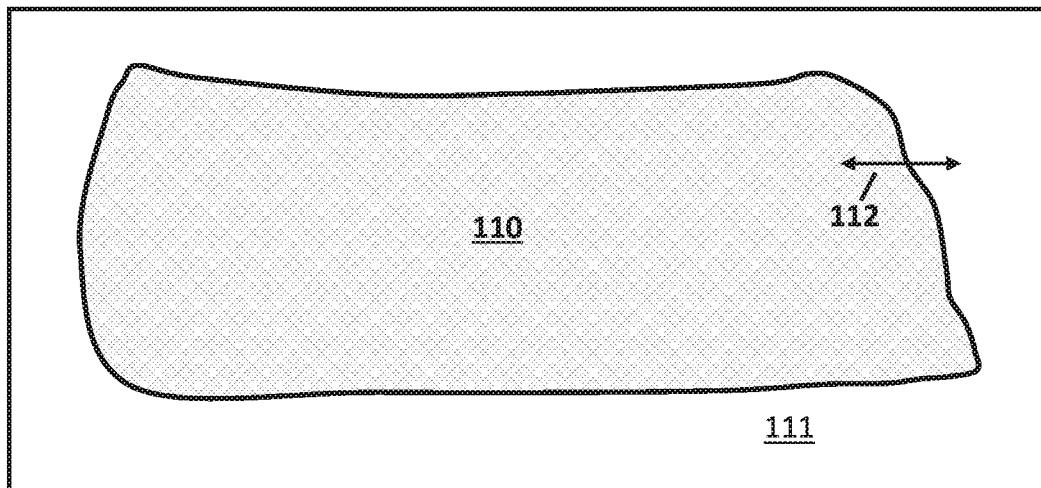
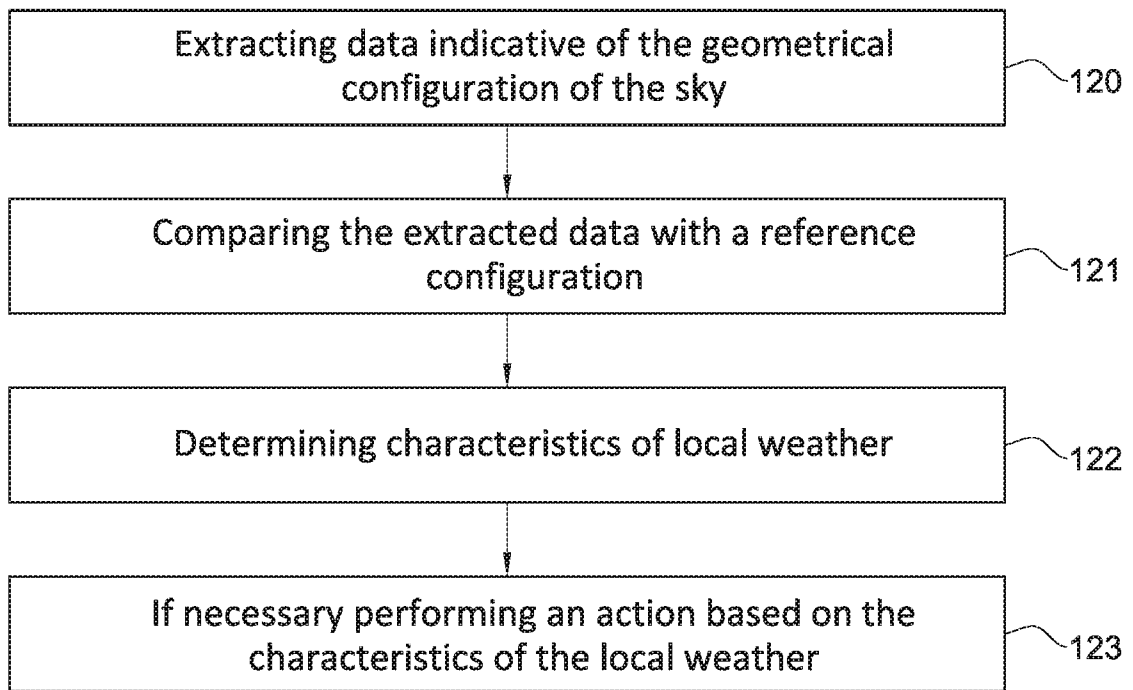
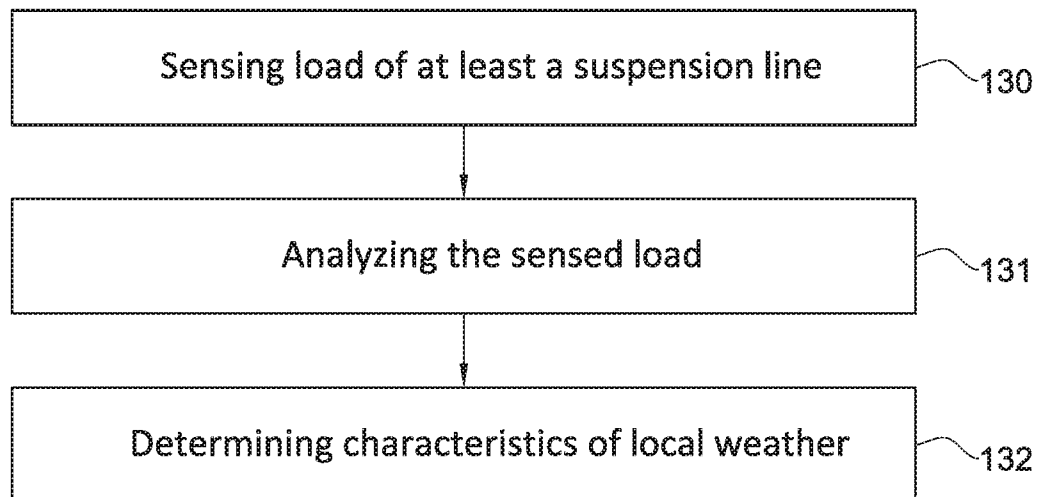


Fig. 11

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**Fig. 12****Fig. 13**

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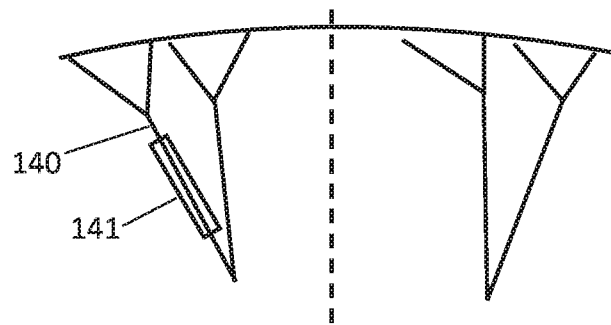


Fig. 14

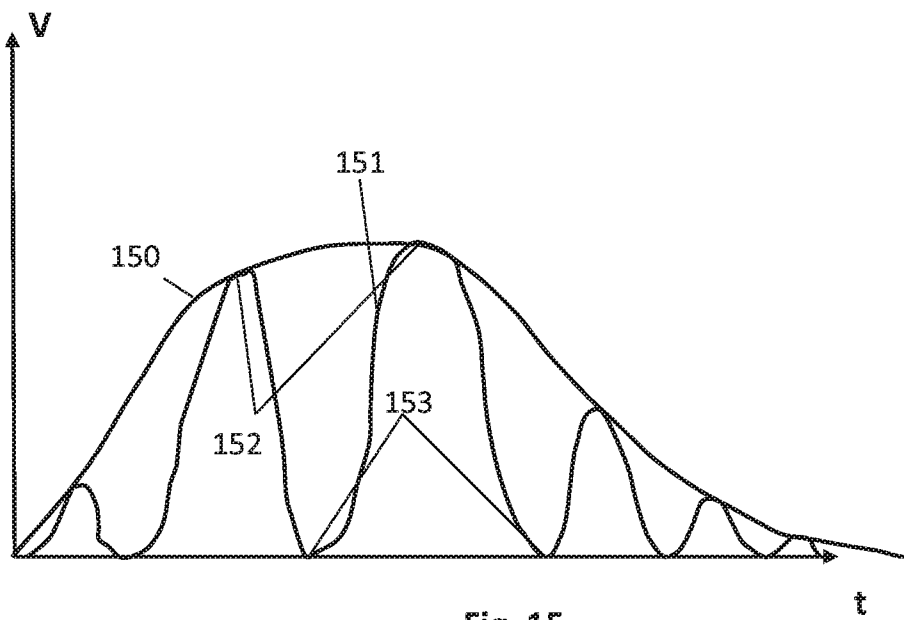


Fig. 15

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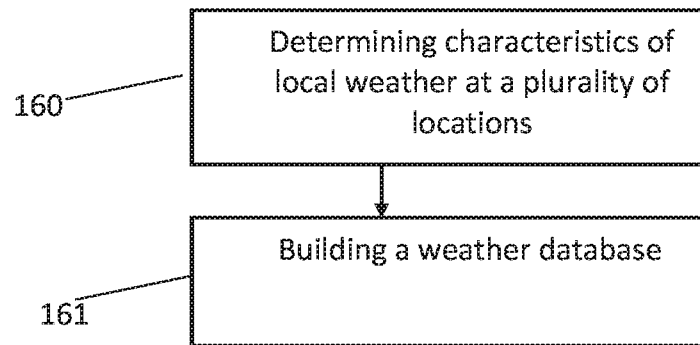


Fig. 16

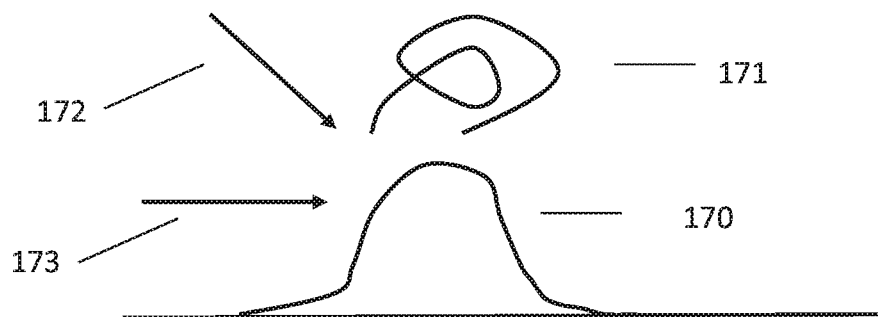


Fig. 17

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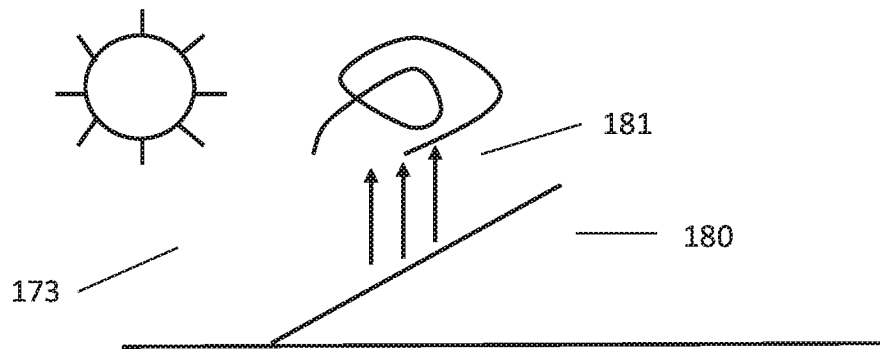


Fig. 18

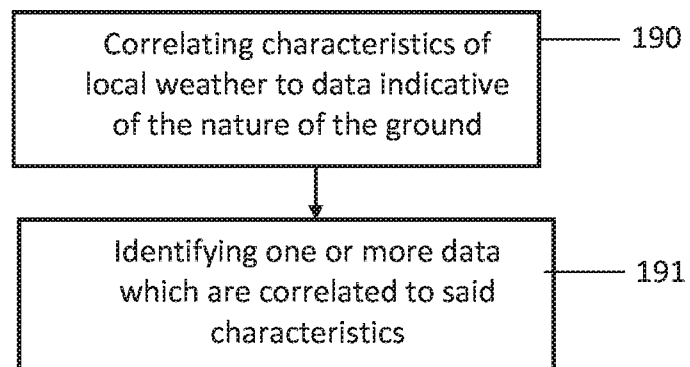


Fig. 19

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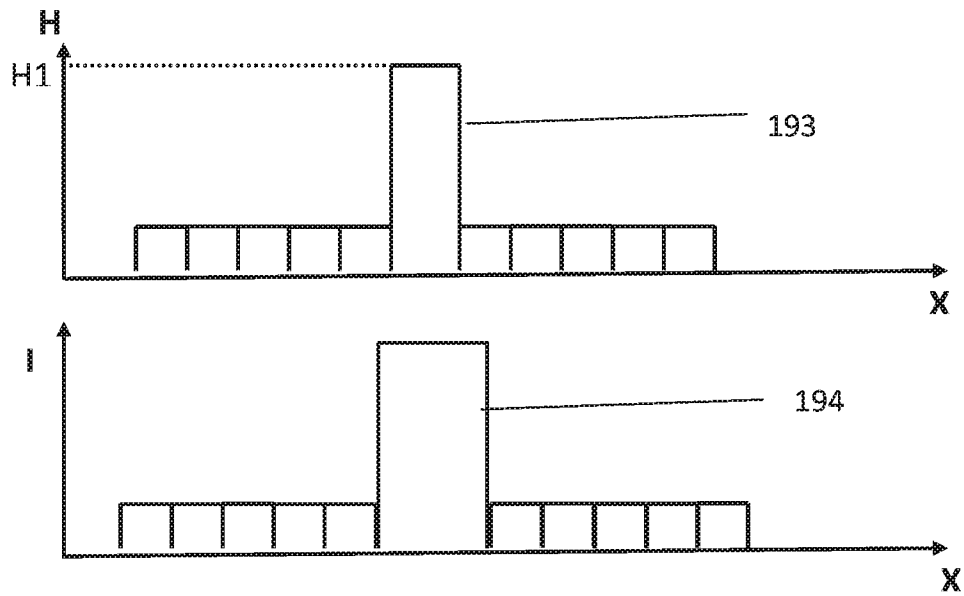


Fig. 19A

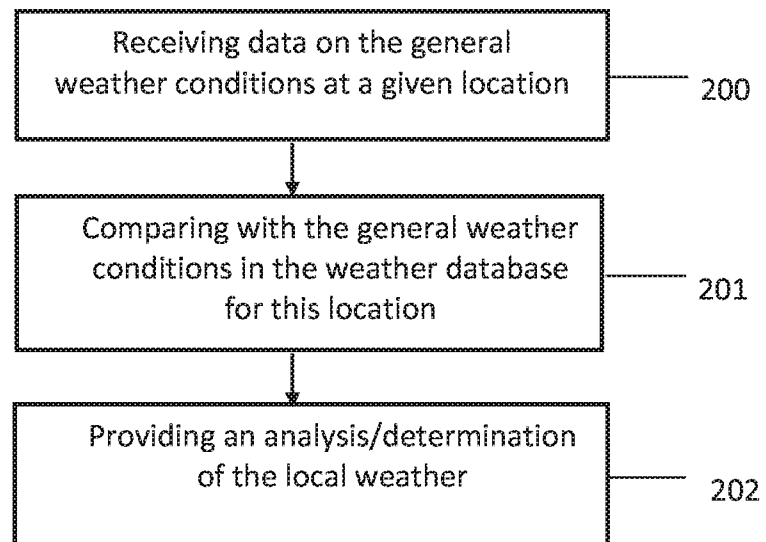
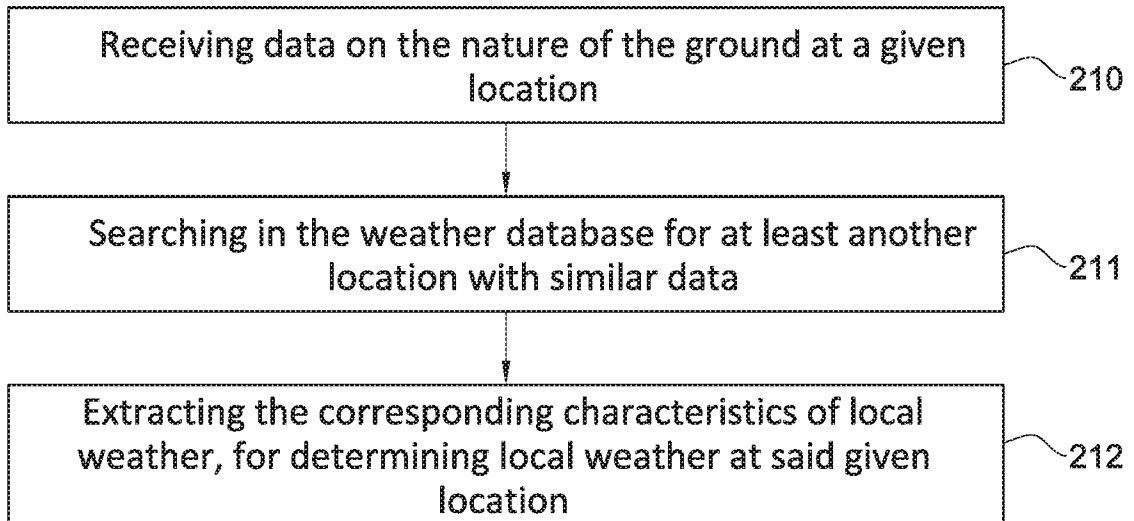
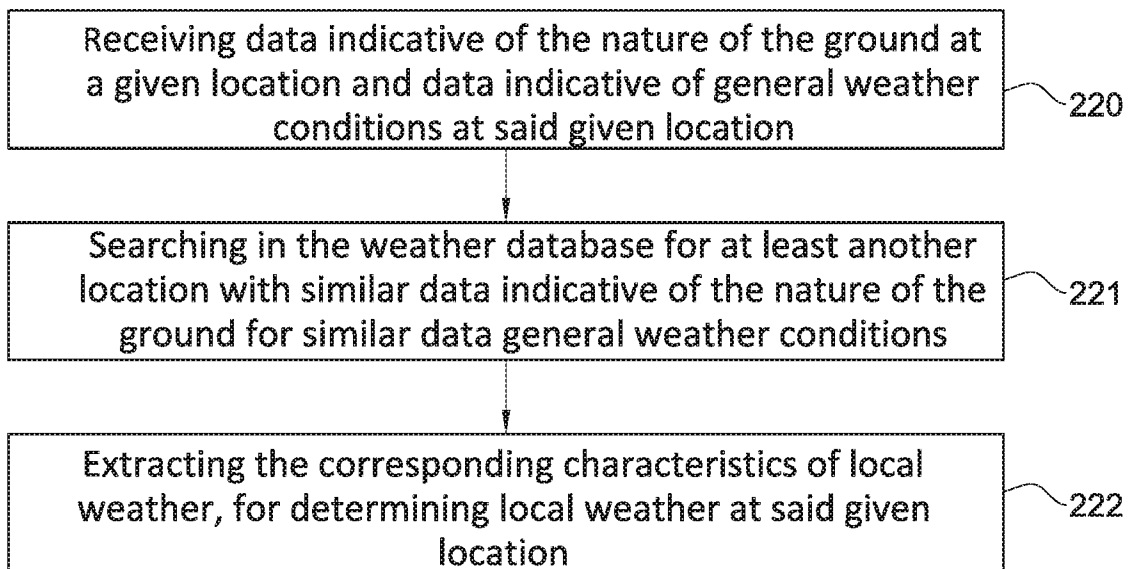
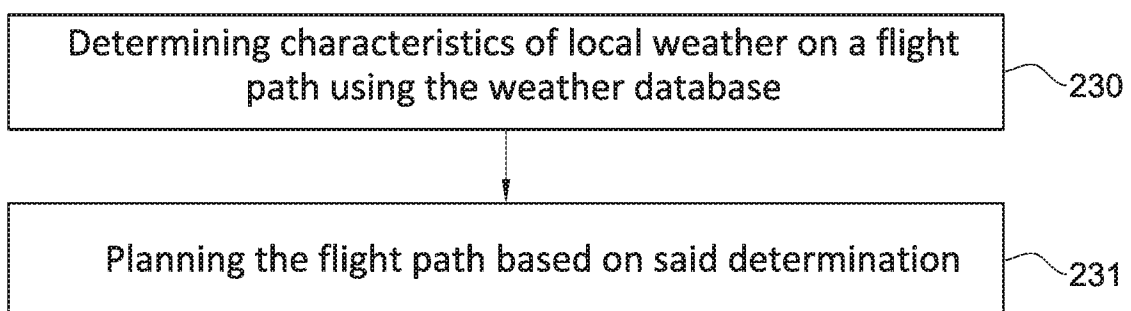


Fig. 20

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**Fig. 21****Fig. 22****Fig. 23**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IL2017/050530

A. CLASSIFICATION OF SUBJECT MATTER IPC (2017.01) B64D 17/00, G05D 1/00, G06F 19/00 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 (2017.01) B64D 17/00, G05D 1/00, G06F 19/00, B64D 17/34, G05D 1/12 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: FamPat database, Derwent Innovation Search terms used: weather, measurement, airfoil, parachute, parafoil, canopy, sensor, vision, image, condition, information, database, data, telemetry, ground		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2015012969 A2 LOGOS TECHNOLOGIES INC [US]; PULLAM WADE [US]; BAKER PATRICK [US]; FIELDS DAVE [US]; BURNS BRADLEY [US]; AMOUZOU SLLETE [US]; SCHULZ BRYAN [US]; ENGIER JIM [US] 29 Jan 2015 (2015/01/29) Entire Document	1-49
A	US 2013013135 A1 YAKIMENKO OLEG [US]; HEWGLEY CHARLES [US]; BOURAKOV EUGENE [US] 10 Jan 2013 (2013/01/10) Entire Document	1-49
A	US 2007272801 A1 HILLIARD DONALD PATRICK [US]; HILLIARD GLENDA ESNARDO [US]; HILLIARD MICHAEL PATRICK [US]; HILLIARD CHRISTINA ANN [US] 29 Nov 2007 (2007/11/29) Entire Document	1-49
A	DE 4336056 A1 NORD SYSTEMTECHNIK [DE] 27 Apr 1995 (1995/04/27) Entire Document	1-49
☐ 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 23 Aug 2017		Date of mailing of the international search report 24 Aug 2017
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 CHOVER Nimrod Israel Telephone No. 972-5651692

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IL2017/050530

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See extra sheet.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/IL2017/050530

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
WO 2015012969 A2	29 Jan 2015	WO 2015012969 A2	29 Jan 2015
		WO 2015012969 A3	16 Apr 2015
		US 2016137303 A1	19 May 2016
US 2013013135 A1	10 Jan 2013	US 2013013135 A1	10 Jan 2013
		US 8483891 B2	09 Jul 2013
		US 2013013131 A1	10 Jan 2013
		US 8437891 B2	07 May 2013
		US 2013013132 A1	10 Jan 2013
		US 8489256 B2	16 Jul 2013
		US 2013009013 A1	10 Jan 2013
		US 8818581 B2	26 Aug 2014
		US 2014204801 A1	24 Jul 2014
		US 9331773 B2	03 May 2016
		US 2013009014 A1	10 Jan 2013
US 2007272801 A1	29 Nov 2007	US 2007272801 A1	29 Nov 2007
DE 4336056 A1	27 Apr 1995	DE 4336056 A1	27 Apr 1995

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IL2017/050530

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet):

* This International Searching Authority found multiple inventions in this international application, as follows:

Invention/s 1	A system for the measurement of weather	Claim/s 1-20,27,28
Invention/s 2	A weather database	Claim/s 21-26,29-49