US 20170229025A1

(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2017/0229025 A1

KLINGER et al. (43) Pub. Date: Aug. 10, 2017

(54) **UNMANNED VEHICLE, SYSTEM AND METHOD FOR DETERMINING A PLANNED PATH FOR UNMANNED VEHICLES**

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(21) Appl. No.: **15/206,229**

(22) Filed: **Jul. 9, 2016**

Related U.S. Application Data

(60) Provisional application No. 62/291,344, filed on Feb. 4, 2016.

Publication Classification

(51) **Int. Cl.**

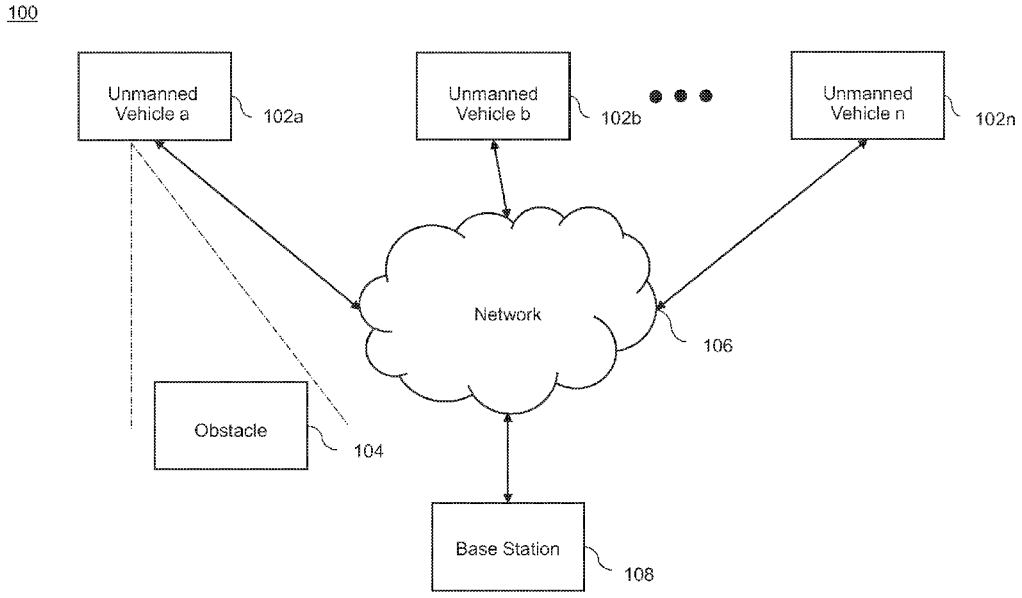
G08G 5/00	(2006.01)
G05D 1/00	(2006.01)
G01S 19/13	(2006.01)
B64C 39/02	(2006.01)

(52) **U.S. Cl.**

CPC ***G08G 5/0039*** (2013.01); ***B64C 39/024*** (2013.01); ***G05D 1/0027*** (2013.01); ***G01S 19/13*** (2013.01); *B64C 2201/021* (2013.01); *B64C 2201/024* (2013.01); *B64C 2201/146* (2013.01); *B64C 2201/141* (2013.01)

(57) **ABSTRACT**

Some embodiments are directed to an unmanned vehicle. The unmanned vehicle can include a memory unit that is configured to store a planned path of the unmanned vehicle. The unmanned vehicle can also include a position unit that is configured to determine a current position of the unmanned vehicle, the position unit further configured to determine a planned position of the unmanned vehicle based on the planned path data stored in the memory unit. The unmanned vehicle can further include a control unit disposed in communication with the position unit, the control unit configured to determine a deviation based on the planned position and the current position of the unmanned vehicle, and control a movement of the unmanned vehicle such that the unmanned vehicle moves along the planned path if the deviation is less than a predetermined threshold.



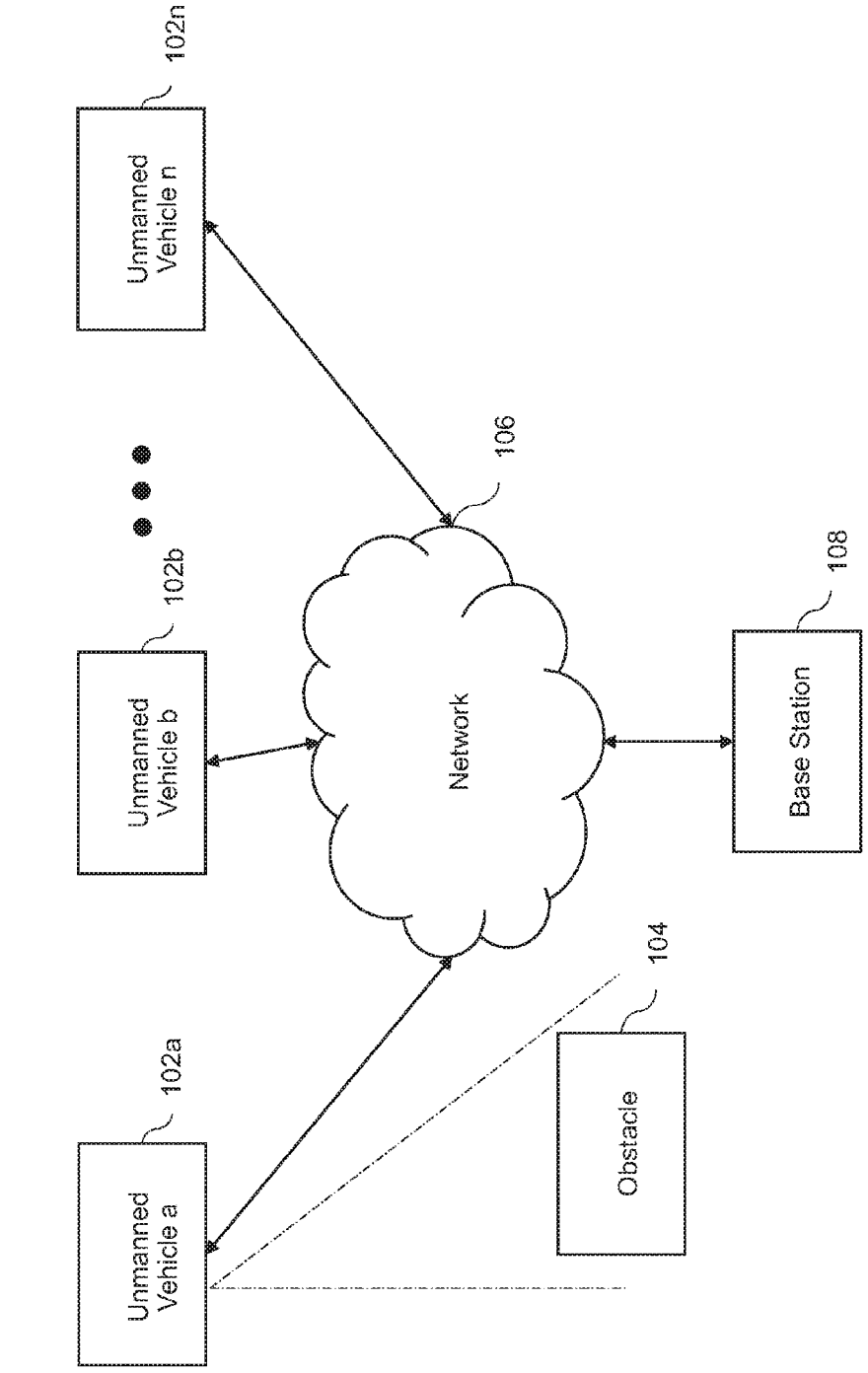

100
Unmanned Vehicle a
102a
Unmanned Vehicle b
102b
Unmanned Vehicle n
102n
Network
106
Obstacle
104
Base Station
108

Fig. 1

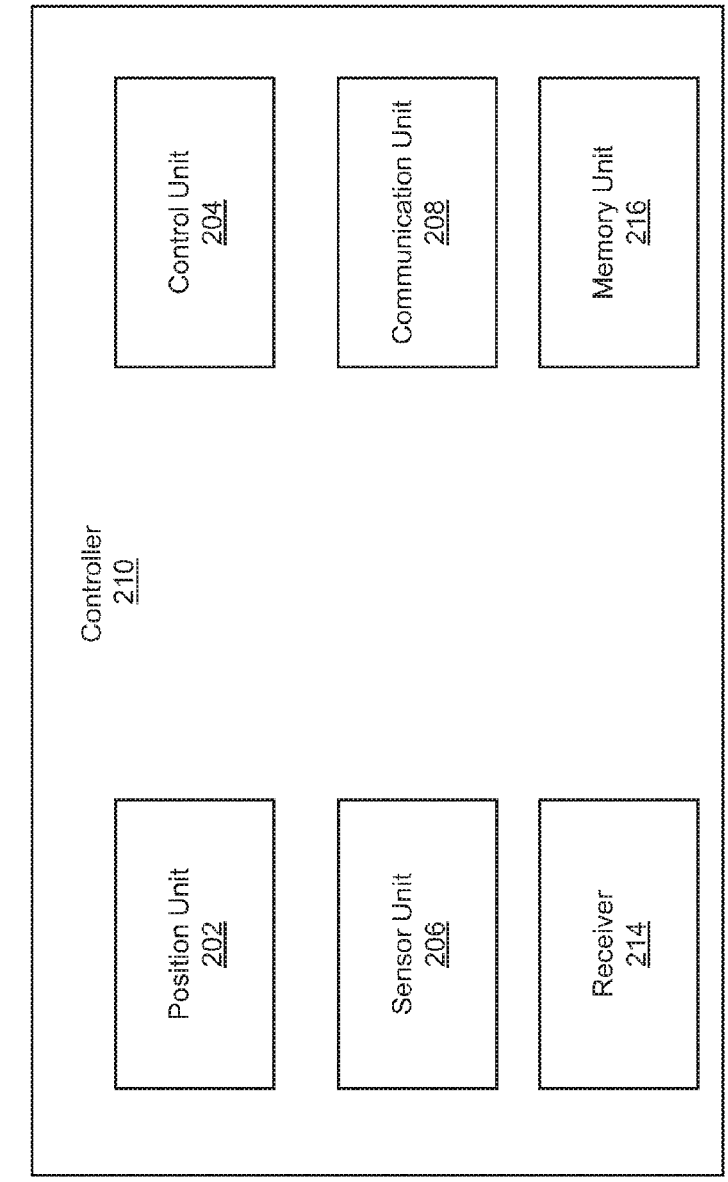

102
Controller
210
Control Unit
204
Communication Unit
208
Memory Unit
216
Position Unit
202
Sensor Unit
206
Receiver
214

Fig. 2

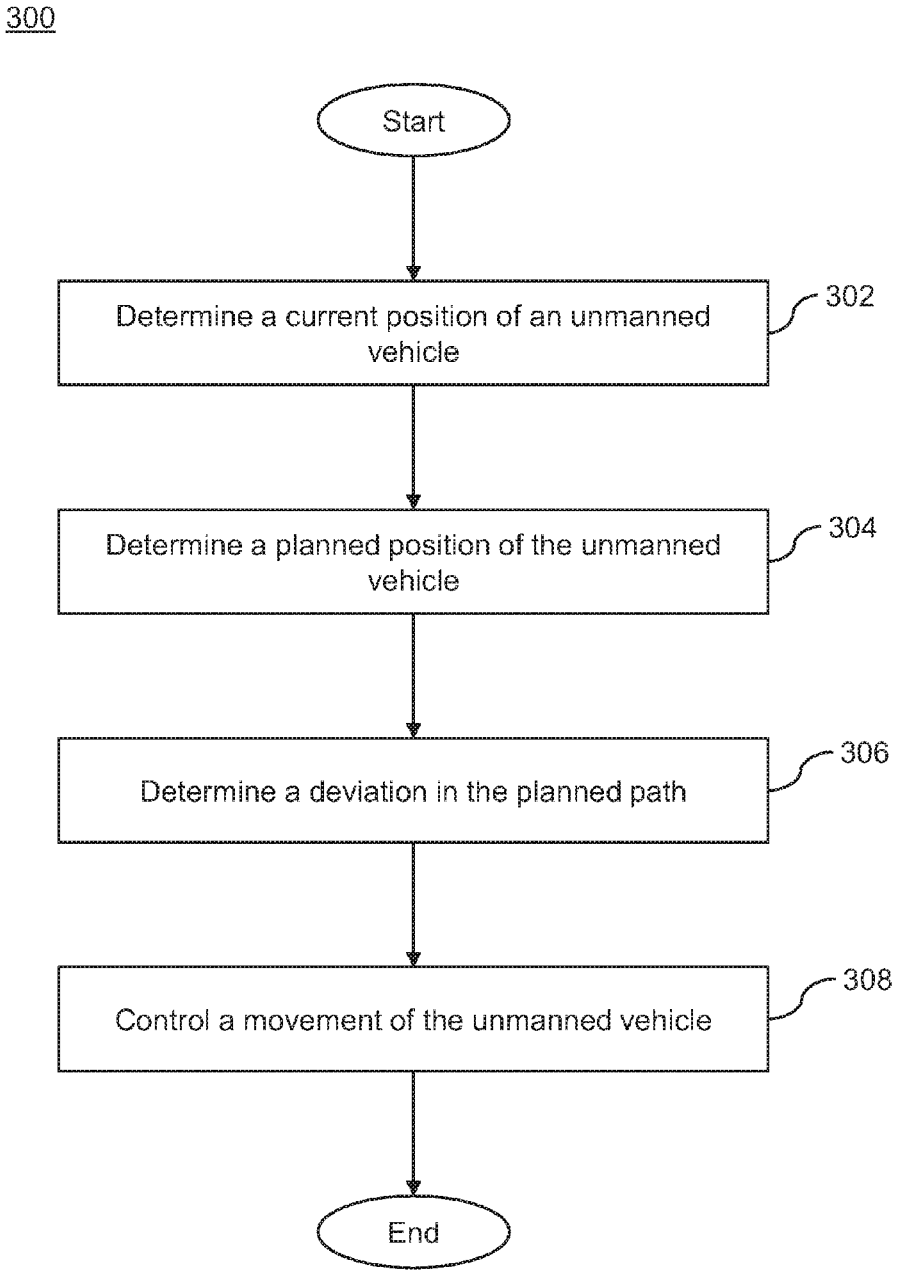

300
Start
Determine a current position of an unmanned vehicle
302
Determine a planned position of the unmanned vehicle
304
Determine a deviation in the planned path
306
Control a movement of the unmanned vehicle
308
End

Fig. 3

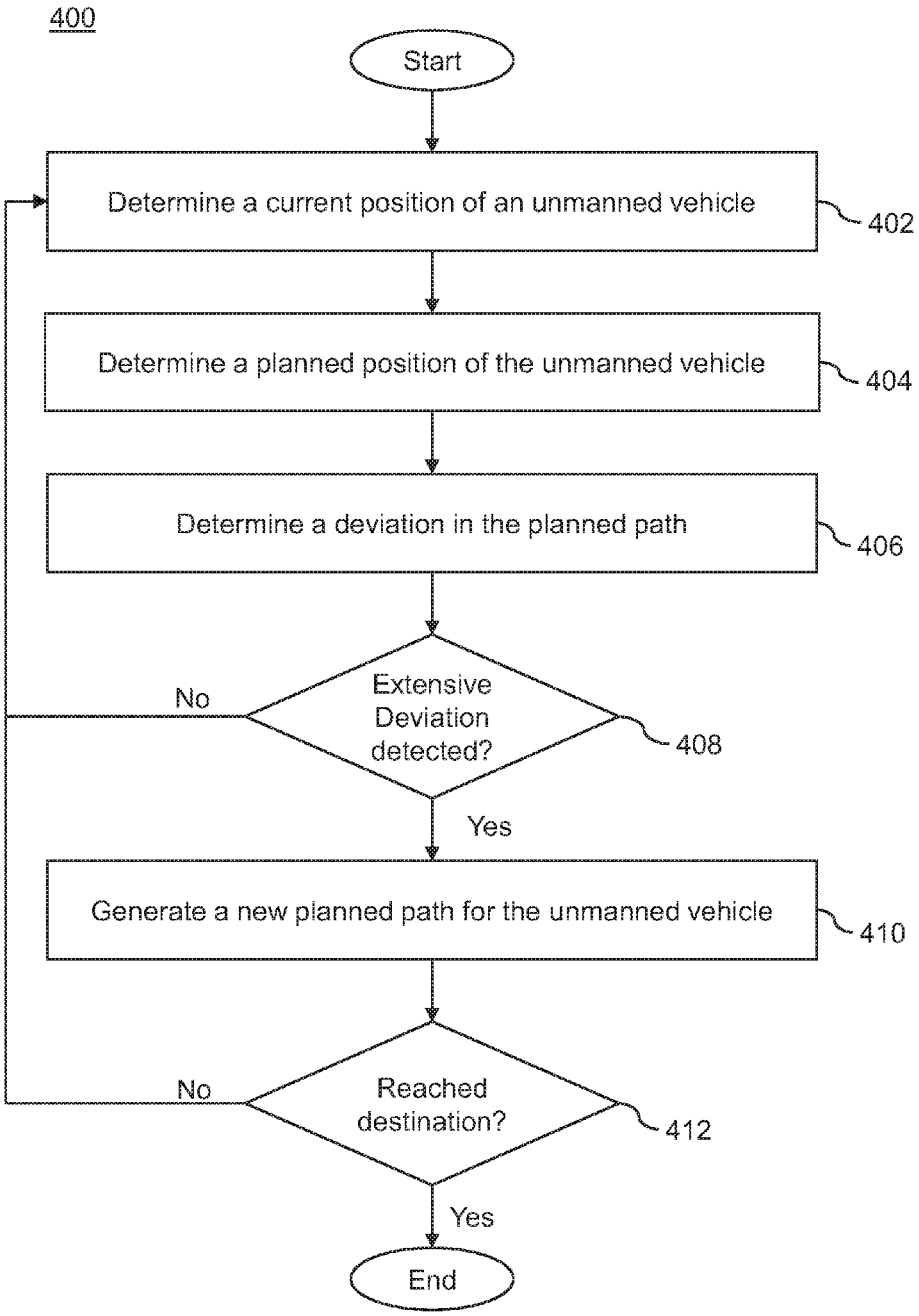

400
Start
Determine a current position of an unmanned vehicle
402
Determine a planned position of the unmanned vehicle
404
Determine a deviation in the planned path
406
Extensive Deviation detected?
408
No
Yes
Generate a new planned path for the unmanned vehicle
410
Reached destination?
412
No
Yes
End

Fig. 4

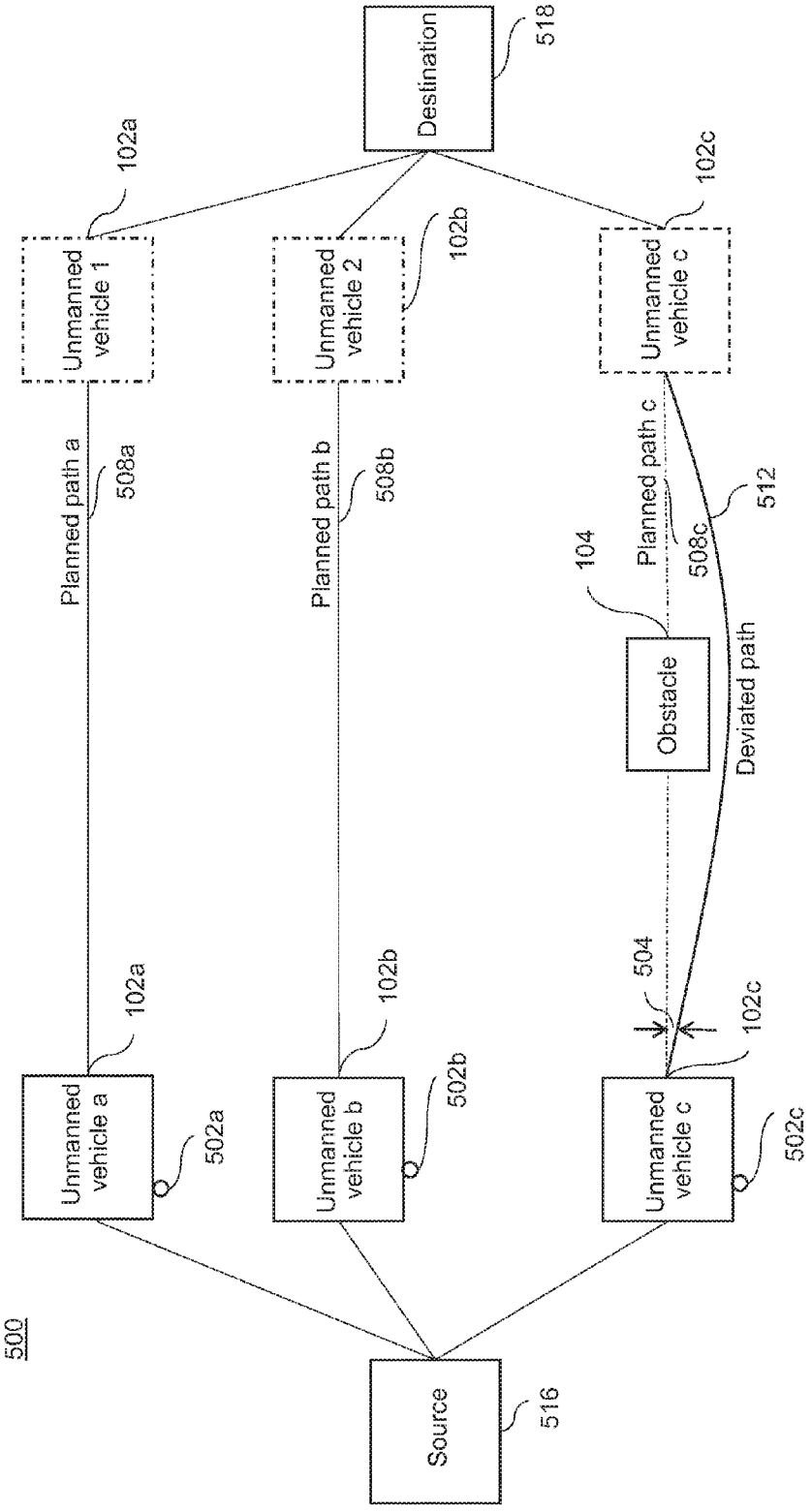

500
Source
516
Destination
518
Unmanned vehicle a
102a
502a
Unmanned vehicle b
102b
502b
Unmanned vehicle c
102c
502c
Unmanned vehicle 1
102a
Unmanned vehicle 2
102b
Unmanned vehicle c
102c
Planned path a
508a
Planned path b
508b
Planned path c
508c
512
Deviated path
Obstacle
104
504

Fig. 5A

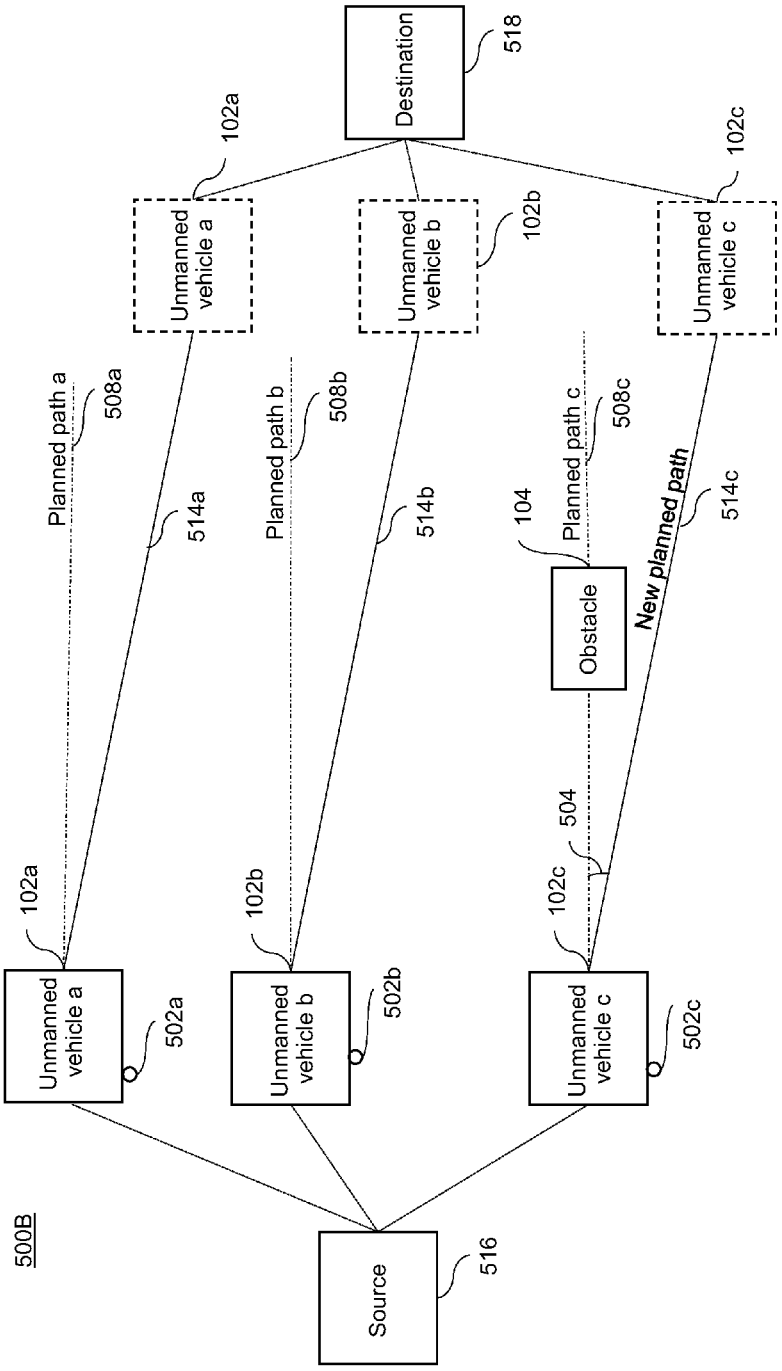

Destination
518
102a
102c
Unmanned vehicle a
Unmanned vehicle b
102b
Unmanned vehicle c
Planned path a
508a
Planned path b
508b
Planned path c
508c
514a
514b
514c
104
Obstacle
New planned path
102a
102b
102c
504
Unmanned vehicle a
502a
Unmanned vehicle b
502b
Unmanned vehicle c
502c
500B
Source
516

Fig. 5B

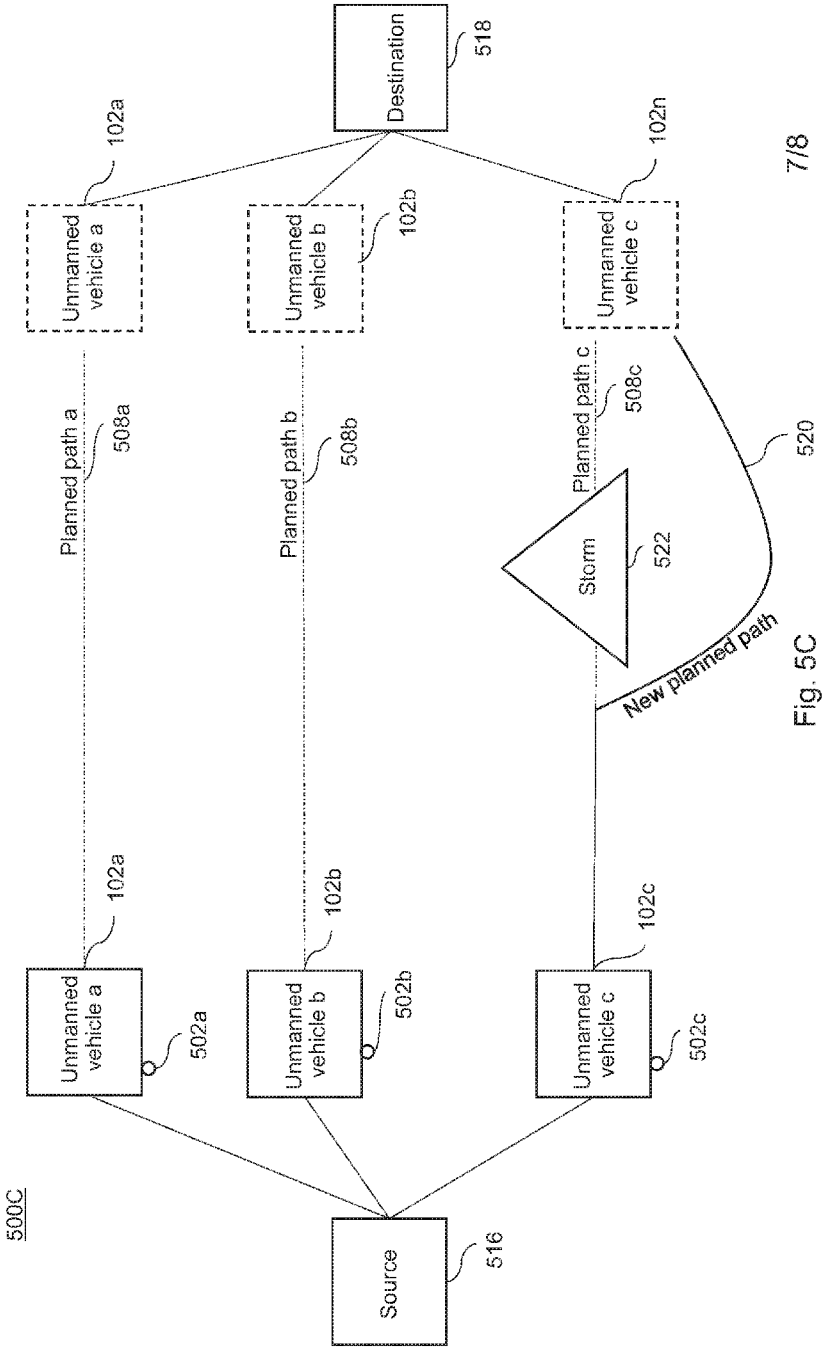

500C
Source
516
Unmanned vehicle a
502a
Unmanned vehicle b
502b
Unmanned vehicle c
502c
102a
102b
102c
Planned path a
508a
Planned path b
508b
Planned path c
508c
Storm
522
New planned path
520
Destination
518
Unmanned vehicle a
Unmanned vehicle b
Unmanned vehicle c
102a
102b
102n

Fig. 5C

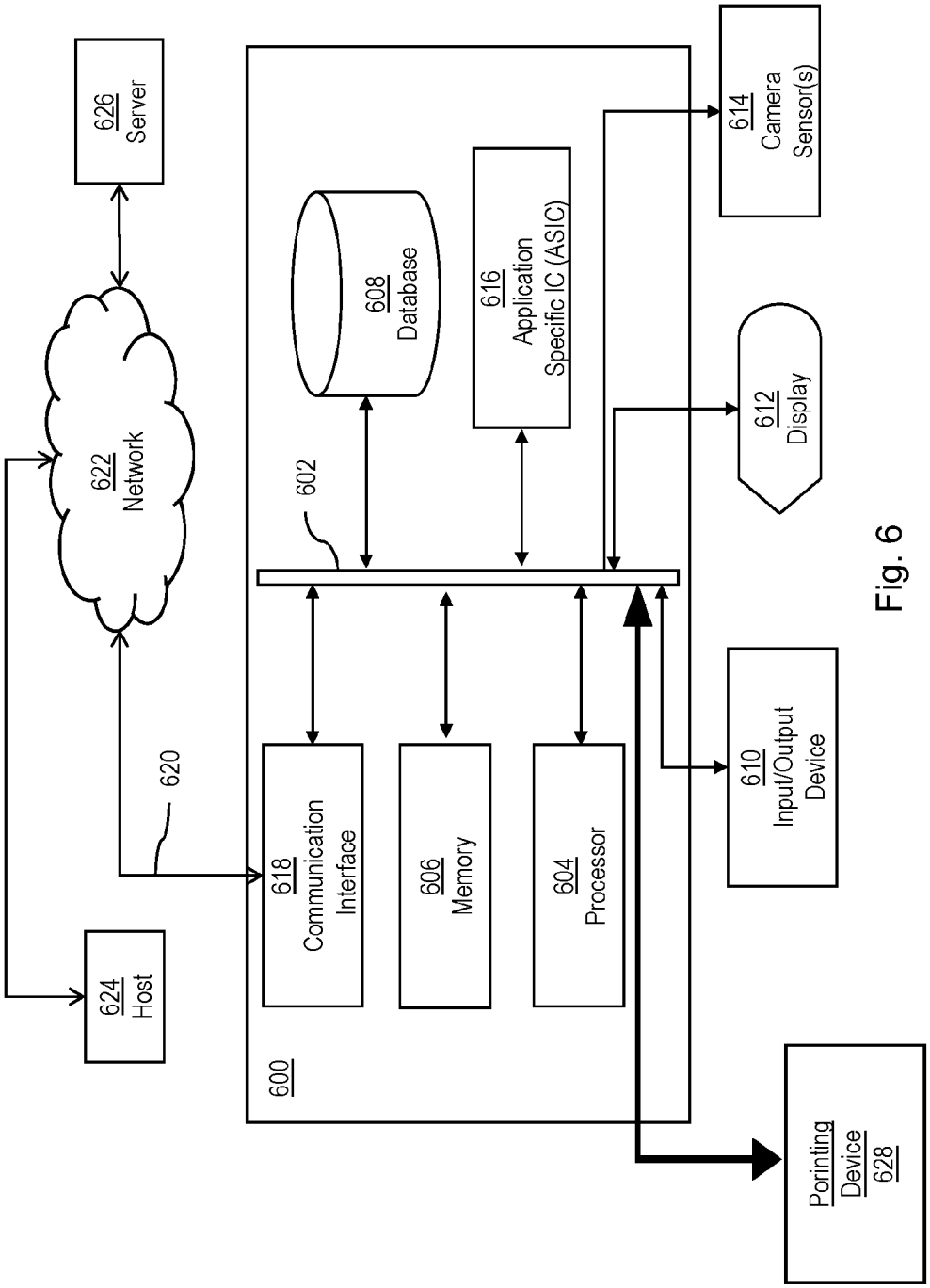

626 Server
622 Network
624 Host
620
600
618 Communication Interface
606 Memory
604 Processor
608 Database
616 Application Specific IC (ASIC)
602
614 Camera Sensor(s)
612 Display
610 Input/Output Device
Pointing Device 628

Fig. 6

UNMANNED VEHICLE, SYSTEM AND METHOD FOR DETERMINING A PLANNED PATH FOR UNMANNED VEHICLES

[0001] PRIORITY INFORMATION

[0002] This Application claims priority to provisional Application 62/291,344 filed on Feb. 4, 2016. The substance of Application 62/291,344 is hereby incorporated in its entirety into this Application.

BACKGROUND

[0003] The disclosed subject matter relates to unmanned vehicles or optionally manned vehicles, systems and methods for controlling unmanned vehicles or optionally manned vehicles. More particularly, the disclosed subject matter relates to systems and methods for determining a planned path for unmanned vehicles or optionally manned vehicles.

[0004] The unmanned vehicle is a vehicle without a person on board, which is capable of sensing their surrounding and navigation on their own. The unmanned vehicle can operate in, but not restricted to, air, water, land, and so forth. The unmanned vehicle can either be autonomous or remotely operated by an operator. Optionally manned vehicles can be operated with or without a person on board. The optionally manned vehicles may enable manual testing of the vehicles before unmanned operation or allow manual control, if necessary, during an unmanned mode of operation.

[0005] Generally, the unmanned vehicles or optionally manned vehicles are vulnerable to collisions with each other and/or with obstacles present in their operational environments. These collisions may result from a lack of geographic information of an obstacle and/or unpredictable environmental conditions. Further, a group of unmanned vehicles may have increased likelihood of such collisions as each of the unmanned vehicles may be subject to similar changes in the environmental conditions.

SUMMARY

[0006] Unmanned vehicles are in danger of colliding with each other (hereinafter referred to as vehicle-to-vehicle collision) or with obstacles present in their operational environments. For example, a single unmanned aerial vehicle, while moving along its trajectory, can collide with obstacles, such as, but not restricted to, buildings, antennas, birds, other aerial vehicles. In other exemplary scenarios, a single unmanned terrestrial, aquatic, oceanic or space vehicle can suffer similar collisions with the obstacles, such as, but not restricted to, trees, rocks, sand banks, coral, orbital debris, and so forth.

[0007] The unmanned vehicle typically collides with the obstacle and/or with other unmanned vehicles due to lack of information regarding their positions in the operational environment of the unmanned vehicle. Also, in case of sudden changes in environmental conditions, it difficult for the unmanned vehicle, to collect information of the obstacle and/or the other unmanned vehicle. The environmental changes may be, but not restricted to, change in wind patterns, low visibility, temperature fluctuations, turbulence, and so forth. Such environmental changes may cause the unmanned vehicles to unpredictably veer off-course and lead to the aforementioned collisions. In some other embodiments, the unmanned vehicle can face deviation from the planned path due to hardware and/or software faults.

[0008] In another exemplary scenario, unmanned vehicles in a fleet may be prone to vehicle-to-vehicle collisions or collisions with the obstacles as each of the unmanned vehicle is subject to similar unpredictable changes in their operational environments.

[0009] Optionally manned vehicles can also suffer from collisions similar to the unmanned vehicles due to various reasons including those described above with reference to the unmanned vehicles.

[0010] Some related arts mitigate such collisions by enabling an unmanned vehicle to calculate a planned path. The planned path is designed to impede vehicle-to-vehicle collisions and/or collisions with known obstacles. However, due to unpredictable environmental conditions including, but not restricted to, unexpected obstacles and rough weather, the unmanned vehicles can deviate from their planned paths. The deviations may be minor in nature or major depending on the severity of the environmental conditions. For example, minor gusts of wind may cause deviations lesser than deviations caused by hurricane force winds.

[0011] In some related arts, the unmanned vehicle calculates a new path after deviation from its planned path. The calculated path may be, but not restricted to, a short term path, a long term path and/or a combination of both. Additionally, the deviation faced by the unmanned vehicle, because of any of the reasons stated above, can be a slight or a minor deviation and/or an extensive or a major deviation. A slight or a minor deviation can be due to minor obstacles such as, but not restricted to, a minor gust of wind, birds, and the like. In another exemplary scenario, the unmanned vehicle can face an extensive or a major deviation due to presence of large obstacles. The large obstacles can include, but not restricted to, hurricane force winds, heavy rain, orbital debris, bodies of water, an aircraft, and so forth.

[0012] However, in some related arts, the unmanned vehicle calculates and executes a new planned path irrespective of a severity or a magnitude of the deviation. For example, if the deviation in the planned path is slight or minor, and the unmanned vehicle generates a new planned path, then the unmanned vehicle may require more time to reach an intended destination, and the journey may be fuel inefficient. Further, in some cases, calculating a new planned path repeatedly due to minor deviations may lead to collisions with other unmanned vehicles and/or obstacles due to extreme and frequent changes in planned paths. Therefore, it may be inefficient to re-calculate a new planned path every time the unmanned vehicle detects a deviation from its planned path.

[0013] Further, in some related arts, the unmanned vehicle calculates and executes a new planned path due to deviations caused by hardware and/or software faults in the unmanned vehicle. In such cases, the calculation of the new planned path can be erroneous leading to collisions with other unmanned vehicles and/or obstacles. Further, calculation of new planed paths repeatedly to compensate for faults or defects can be inefficient.

[0014] It may therefore be beneficial to provide an unmanned vehicle, a system, and a method of use thereof, that address at least one of the above issues. For example, it may be beneficial to provide an unmanned autonomous vehicle that can appropriately determine when to calculate and execute a new planned path.

[0015] It may therefore be beneficial to provide an unmanned vehicle, a system, and a method of use thereof, that address at least one of the above and/or other disadvantages. In particular, in may be beneficial to provide an unmanned vehicle, a system, and a method to employ deviation limits into software/hardware used by the unmanned vehicle. For example, it may be beneficial to configure an unmanned vehicle that can calculate and execute a new planned path in case of extensive or major deviations and/or abstain from new path calculation in case of very slight or minor deviations.

[0016] It may therefore be beneficial to provide an unmanned vehicle, a system, and a method of use thereof, that address at least one of the above and/or other disadvantages. In particular, it may be beneficial to provide an unmanned vehicle, a system, and a method to reduce errors in coordination between unmanned vehicles of a fleet due to repeated path calculations. For example, it may be beneficial to arrange an unmanned vehicle, a system that can decide whether a new planned path is computationally and/or mechanically efficient or not, and help in coordination between the unmanned vehicle with other unmanned vehicles in the fleet and/or with a base station.

[0017] It may therefore be beneficial to provide an unmanned vehicle, a system, and a method of use thereof, that address at least one of the above and/or other disadvantages. In particular, it may be beneficial to provide an unmanned vehicle, a system, and a method for detecting a non-conforming unmanned vehicle in a fleet based on a deviation pattern. Such non-conformance may be due to hardware and/or software faults, and can result in unreliable movement of the unmanned vehicle. For example, it may be beneficial to arrange an unmanned vehicle, a system, and a method that can determine a deviation of the unmanned vehicle, and compare the deviation to a conformance threshold in order to determine whether the unmanned vehicle is non-conforming. Identifying and flagging one or more non-conforming vehicles in the fleet can help in coordination between the other conforming unmanned vehicles in the fleet, thereby avoiding or impeding any collisions.

[0018] Some embodiments are therefore directed to a method of controlling an unmanned vehicle operatively coupled to a controller. The method can include determining, by the controller, a current position of the unmanned vehicle; determining, by the controller, a planned position of the unmanned vehicle based on a planned path of the unmanned vehicle; determining, by the controller, a deviation based on the planned position and the current position of the unmanned vehicle; and controlling, by the controller, a movement of the unmanned vehicle such that the unmanned vehicle moves along the planned path if the deviation is less than a predetermined threshold.

[0019] Some other embodiments are directed to an unmanned vehicle. The unmanned vehicle can include a memory unit that is configured to store a planned path of the unmanned vehicle. The unmanned vehicle can also include a position unit that is configured to determine a current position of the unmanned vehicle, the position unit further configured to determine a planned position of the unmanned vehicle based on the planned path stored in the memory unit. The unmanned vehicle can further include a control unit disposed in communication with the position unit, the control unit configured to determine a deviation based on the planned position and the current position of the unmanned vehicle, and control a movement of the unmanned vehicle such that the unmanned vehicle moves along the planned path if the deviation is less than a predetermined threshold.

[0020] Yet other embodiments are directed to a system including multiple unmanned vehicles spaced from each other. The system including the unmanned vehicles, wherein each of the unmanned vehicles can include a memory unit that is configured to store a planned path of the unmanned vehicle. The system including the unmanned vehicles, wherein each of the unmanned vehicle can also include a position unit that is configured to determine a current position of the unmanned vehicle, the position unit further configured to determine a planned position of the unmanned vehicle based on the planned path stored in the memory unit. The system including the unmanned vehicles, wherein each of the unmanned vehicles can also include a control unit disposed in communication with the position unit. The controller is configured to determine a deviation based on the planned position and the current position of the unmanned vehicle, and determine a new planned path for the unmanned vehicle if the deviation is greater than or equal to the predetermined threshold. The controller is further configured to communicate the new planned path to the other unmanned vehicles, and control a movement of the unmanned vehicle such that the unmanned vehicle moves along the new planned path.

[0021] In other embodiments, a deviation of an unmanned vehicle from its planned path is determined and compared with a conformance threshold. If the deviation is greater than or equal to the conformance threshold, the unmanned vehicle is flagged as a non-conforming unmanned vehicle. Further, the conformance threshold can be a predetermined value that is part of planned path data. Moreover, the conformance threshold can be equal to predetermined threshold used for calculating a new planned path.

[0022] As mentioned above, current related art technologies usually do not modify their behaviors in response to a combination of external factors (say, a vehicle veering off course unexpectedly) and in conjunction with a threshold parameter range (say, + or −20% in velocity, range, altitude, etc.). Some disadvantages of this strategy are that small deviations (say, 5%) could cause a vehicle to instantly re-process its planned path, which may unnecessarily consume processing resources. Additionally, such a re-calculation might be unnecessary for collision avoidance if other vehicles are well spaces from the vehicle that finds itself off-course.

[0023] Some of the disclosed embodiments address this problem by establishing parameters that would signify safe and unsafe limits on vehicle performance. For example, deviating from certain spatial, speed, acceleration, yaw, roll, pitch, or other thresholds could cause the vehicle to re-calculate a new planned path. Additionally, the vehicle may utilize a time parameter before initializing a correction to this deviation to allow one or more neighboring vehicles to correct their own paths in conjunction with the newly corrected planned path of the first vehicle.

[0024] A further advantage of such an approach is that the initial vehicle can evaluate statistically how far out of range any of the aforementioned parameters is and make a decision to perform self-correction without disturbing each of the other neighboring vehicles. Finally, an off-course vehicle may not even need to perform any correction whatsoever (such as a gust of wind passing that tugs and pushes, but

ultimately returns the vehicle to its initial trajectory). By utilizing this approach in parallel with negative feedback systems such as phase-locked loops, PID controllers, etc., significant RF bandwidth and processing resources can be preserved for numerous higher priority applications.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] The disclosed subject matter of the present application will now be described in more detail with reference to exemplary embodiments of the apparatus and method, given by the way of example, and with reference to the accompanying drawing, in which:

[0026] FIG. **1** is an exemplary system of unmanned vehicles in accordance with the disclosed subject matter.

[0027] FIG. **2** illustrates components of one of the unmanned vehicles in accordance with the disclosed subject matter.

[0028] FIG. **3** is a method for detecting a deviation in a planned path by using an unmanned vehicle in accordance with the disclosed subject matter.

[0029] FIG. **4** is a method for detecting a deviation in a planned path by using an unmanned vehicle in accordance with the disclosed subject matter.

[0030] FIG. **5**A is an exemplary environment for detecting a minor deviation in a planned path by an unmanned vehicle in accordance with the disclosed subject matter.

[0031] FIG. **5**B is an exemplary environment for detecting a major deviation and path correction by an unmanned vehicle is accordance with the disclosed subject matter.

[0032] FIG. **5**C is an exemplary environment for detecting an environmental condition in a planned path and path correction by an unmanned vehicle in accordance with the disclosed subject matter.

[0033] FIG. **6** is a computer system that can be used to implement various exemplary embodiments of the disclosed subject matter.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0034] A few inventive aspects of the disclosed embodiments are explained in detail, below with reference to various figures. Exemplary embodiments are described to illustrate the disclosed subject matter, not to limit the scope, which is defined by the claims. Those of ordinary skill in the art will recognize a number of equivalent variations of the various features provided in description that follows.

I. Unmanned Vehicle

[0035] FIG. **1** is an exemplary system **100** for determining a path for the unmanned vehicle **102** in accordance with the disclosed subject matter.

[0036] FIG. **1** illustrates the system **100** that includes unmanned vehicles **102***a-n,* hereinafter referred to as an unmanned vehicle **102** and collectively referred to as unmanned vehicles **102**. The unmanned vehicle **102**, and embodiments are intended to include or otherwise cover any type of unmanned vehicle, including an unmanned aerial vehicle, an unmanned terrestrial vehicle, a drone, a gyrocopter, an unmanned oceanic vehicle, an unmanned space vehicle, and the like. In some embodiments, the unmanned aerial vehicle can be, but not restricted to, an unmanned aerial surveillance vehicle, a drone, a recreational toy, and so forth. In fact, embodiments are intended to include or otherwise cover any type of unmanned vehicle that may stay geostationary in the sky and/or fly at considerable height. The unmanned aerial vehicle **102** is merely provided for exemplary purposes, and the various inventive aspects are intended to be applied to any unmanned autonomous vehicle.

[0037] In some other embodiments, the unmanned vehicle **102** may be an optionally manned vehicle. The optionally manned vehicle, and embodiments are intended to include or otherwise cover any type of optionally manned vehicle, including an optionally manned aerial vehicle, an optionally manned terrestrial vehicle, a drone, a gyrocopter, an optionally manned oceanic vehicle, an optionally manned space vehicle, and the like. In fact, embodiments are intended to include or otherwise cover any type of optionally manned vehicle.

[0038] In an exemplary scenario, the unmanned vehicle **102** can be a fixed-wing unmanned aircraft. In some other exemplary scenarios, the unmanned vehicle **102** can be a rotorcraft.

[0039] In alternative embodiments, the system **100** can also include one or more unmanned vehicles and optionally manned vehicle.

[0040] In some embodiments, the unmanned vehicle **102** can be manually controlled by an operator present at a base station **108**. In some embodiments, the unmanned vehicle **102** may be autonomously controlled, which involves an operator entering and/or selecting one or more attributes and subsequent autonomous control of the unmanned vehicle **102** based on entered and/or selected parameters. In fact, embodiments are intended to include or otherwise cover any type of techniques, including known, related art, and/or later developed technologies to control the unmanned vehicle **102**.

[0041] For operating purposes, the unmanned vehicle **102** and its components (not shown) can be powered by a power source to provide propulsion. The power source can be, but not restricted to, a battery, a combustion engine, fossil fuel, a fuel cell, a photovoltaic cell, a solar cell, and so forth. In fact, embodiments are intended to include or otherwise cover any type of power source to provide power to the unmanned vehicle **102** for its operations.

[0042] In some embodiments, the unmanned vehicle **102** can have, but not restricted to, rotors, propellers, and flight control surfaces that control movements and/or orientation of the unmanned vehicle **102**, and the like. In fact, embodiments are intended to include or otherwise cover any other component that may be beneficial for controlling movements and/or orientation of the unmanned vehicle **102**.

[0043] The planned path for the unmanned vehicle **102** may be a predefined path between a source and a destination. Also, the planned path for the unmanned vehicle **102** may be an optimal path between the source and the destination in terms of fuel or power consumption, travel time, collision avoidance, jurisdictional requirements, mission requirements (e.g., stealth), weather etc. The planned path can include, but not restricted to, a series of positions, speeds, altitudes, headings, and the like. Further, each position of the planned path may be linked to a corresponding speed, location, altitude and heading of the unmanned vehicle **102**. In an exemplary scenario, a first position for the unmanned vehicle **102** in the series of positions may coincide with the source, while a last position may coincide with the destination. In some embodiments, the planned path may involve a

round trip, and therefore, the source may coincide with the destination. The planned paths may also be segmented, such as a first planned path from the source to site **1** (not shown), a second planned path from site **1** to site **2** (not shown), and a third planned path from site **2** to the destination.

[0044] Further, in some embodiments, the unmanned vehicle **102** can also include, but not restricted to, a processor (not shown), a memory (not shown), and the like. The processor (not shown) can be configured to generate a planned path and/or execute the planned path on receiving a signal from the companion unmanned or optionally manned vehicles, the base station **108**, an external communication device, and the like. In some embodiments, the processor of unmanned vehicle **102** can be a single core processor. In alternate embodiments, the processor can be a multi core processor. Embodiments are intended to include or otherwise cover any type of processor, including known, related art, and/or later developed technologies to enhance capabilities of processing data and/or instructions.

[0045] In addition, the memory (not shown) of the unmanned vehicle **102** can store data used to generate a planned path for the unmanned vehicle, geographical location of an obstacle **104**, and so forth. The memory can be used to store instructions that can be processed by the processor. Embodiments are intended to include or otherwise cover any type of memory, including known, related art, and/or later developed technologies to enhance capabilities of storing data and/or instructions.

[0046] The base station **108** can be a fixed base station **108** or a mobile base station **108**. In some other embodiments, the mobile base station **108** may include, but not restricted to, an unmanned aerial vehicle, an unmanned terrestrial vehicle, and the like. It may also be contemplated that the base station **108** may be, but not restricted to, an electronic device, such as a smartphone, a laptop, a remote control device, and the like. In fact, embodiments are intended to include or otherwise cover any type of base station **108**, including known, related art, and/or later developed technologies to communicate with other unmanned vehicles **102**.

[0047] Moreover, each of the unmanned vehicles **102** may communicate with the base station **108**, or companion unmanned vehicles through a communication network **106**. In some embodiments, the unmanned vehicle **102** may communicate with the base station **108** via the communication network **106** to notify a change in the planned path made by the unmanned vehicle **102**.

[0048] In some embodiments, the communication network **106** may include a data network such as, but not restricted to, the Internet, local Area Network (LAN), Wide Area Network (WAN), Metropolitan Area Network (MAN), etc. In certain embodiments, the communication network **106** can include a wireless network, such as, but not restricted to, a cellular network and may employ various technologies including Enhanced Data rate for Global Evolution (EDGE), Genera; Packet Radio Service (GPRS), Global System for Mobile communication (GSM), Internet protocol Multimedia Subsystem (IMS), Universal Mobile Telecommunication System (UTMS), etc. In some embodiments, the communication network **106** may include or otherwise cover networks or subnetworks, each of which may include, for example, a wired or wireless data pathway. The communication network **106** may include a circuit-switched voice network, a packet-switched data network, or any other network capable for carrying electronic communications. For example, the network may include networks based on the Internet protocol (IP) or Asynchronous Transfer Mode (ATM), and may support voice usage, for example, VoIP, Voice-over-ATM, or other comparable protocols used for voice data communications. In one implementation, the network includes a cellular telephone network configured to enable exchange of text or SMS messages.

[0049] Examples of the communication network **106** may include, but not limited to, a Personal Area Network (PAN), a Storage Area Network (SAN), a Home Area Network (HAN), a Campus Area Network (CAN), a Virtual Private Network (VPN), an Enterprise Private Network (EPN), Internet, a Global Area Network (GAN), and so forth. Embodiments are intended to include or otherwise cover any type of communication network, including known, related art, and/or later developed technologies to communicate with other unmanned vehicles **102** or the base station **108**.

[0050] In the system **100**, as shown in FIG. **1**, the unmanned vehicle **102** is moving on a planned path. The unmanned vehicle **102** detects the obstacle **104** in its planned path and deviates from its planned path due to the obstacle **104**. In some embodiments, the obstacle **104** can be, but not restricted to, birds, flying objects, hurricane force winds, overhead cables, buildings, antenna, tower, and so forth.

[0051] In some embodiments, the unmanned vehicle **102** detects deviation from the planned path of the unmanned vehicle **102** based on deviation parameters. The deviation parameters may include, but not restricted to, vehicle trajectory parameters, environmental factors, signal parameters, and so forth. In some embodiments, the deviation can be determined with the help of vehicle trajectory parameters. The vehicle trajectory parameters can include, but not restricted to, speed, yaw, pitch, roll, elevation of the unmanned vehicle **102**, and so forth. In an exemplary scenario, the unmanned vehicle **102** may be assigned predefined values of the vehicle trajectory parameters, and if any of the vehicle trajectory parameter changes during the course of journey, the unmanned vehicle **102** is considered as being deviated from its planned path. In fact, embodiments of the present invention are intended to include or otherwise cover any number of vehicle trajectory parameters that determines deviation of the unmanned vehicle **102** from its planned path.

[0052] The deviation in the planned path of the unmanned vehicle **102** can also be due to various environmental factors, for example, heavy winds can force the unmanned vehicle **102** away from its planned path. The environmental factors may be, but not restricted to, wind speed turbulence, weather, visibility, and the like.

[0053] In yet another embodiment, the unmanned vehicle **102** detects deviation in the planned path of the unmanned vehicle **102** based on signal parameters of the unmanned vehicle **102** such as, but not restricted to, signal strength, transmitter/receiver data rate, transmitter/receiver sensitivity, transmitter/receiver power, a phase of the signal, and so forth.

[0054] The unmanned vehicle **102** is configured to communicate with the other companion unmanned vehicles **102**. In some embodiments, the unmanned vehicle **102** may communicate with the other companion unmanned vehicles **102** through, but not restricted to, a communication network such as the communication network **106** of the system **100**.

[0055] Further, the functioning of the unmanned vehicle **102** is described in greater detail below in conjunction with FIG. **2**.

II. Functioning of the Unmanned Vehicle

[0056] FIG. **2** illustrates components of the unmanned vehicle **102**, in accordance with the disclosed subject matter. As discussed, the unmanned vehicle **102** can be configured to detect the deviation from the planned path, and thereafter, move back to the planned path, modify the planned path or generate a new planned path. In some exemplary scenarios, the deviation from the planned path may be due to the presence of the obstacle **104** in the planned path, changes in vehicle trajectory parameters, variations in environmental factors, changes in signal parameters, and so forth.

[0057] In some embodiments, the unmanned vehicle **102** may have a controller **210** that may include, but not restricted to, a position unit **202**, a control unit **204**, a sensor unit **206**, a communication unit **208**, a receiver **214**, and a memory unit **216**. Also, controller **210** may have multiple such components. The controller **210** may be, but not restricted to, a wireless controller and/or a wired controller. In fact, embodiments of the disclosed subject matter are intended to include or otherwise cover any number of components in the unmanned vehicle **102** to detect the deviation from the planned path. In some other embodiments, the controller **210** can be situated outside the unmanned vehicle **102**. In an exemplary scenario, the controller **210** is at the base station **108** and can control the movement of the unmanned vehicle **102**. Also in other exemplary scenario, the movement of the unmanned vehicle **102** can be controlled by a controller of another unmanned vehicle.

[0058] The controller **210** is configured to control various operations of the unmanned vehicle **102** including, but not limited to, a movement of the unmanned vehicle **102**, controlling and coordinating operations between various components of the unmanned vehicle **102**, interfacing with other unmanned vehicles **102**, processing information received from the base station **108** and/or other unmanned vehicles **102**, detecting deviation of the unmanned vehicle **102** from the planned path, generating a new planned path for the unmanned vehicle **102**, and so forth. In fact, embodiments of the disclosed subject matter are intended to include or otherwise cover any operation of the controller **210** that may be beneficial to detect any deviation from the planned path.

[0059] In some embodiments, the position unit **202** can be configured to determine a position of the unmanned vehicle **102** in the system **100**. The position unit **202** may determine the position of the unmanned vehicle **102** through various techniques such as, but not restricted to, ranging tones, relative vehicle telemetry, optical imaging, radar based techniques, global positioning system (GPS), inertial navigation, microwave ranging techniques, ultra sound ranging techniques, laser ranging, or a combination thereof. The embodiments of the current disclosed subject matter are intended to include or otherwise cover any technique, including known, related art, and/or later developed technologies that may be beneficial for determining the position of the unmanned vehicle **102**.

[0060] In an exemplary scenario, the unmanned vehicle **102** uses a GPS based system to determine its position. In another scenario, the unmanned vehicle **102** may combine GPS data with inertial navigation to determine its position.

[0061] In some embodiments, the position unit **202** is configured to determine a current position 'P_c' of the unmanned vehicle **102**. In an exemplary scenario, the position unit **202** gathers data from the surroundings (e.g., a landmark) and/or companion unmanned vehicles and then determines a current position 'P_c' of the unmanned vehicle **102** based on the gathered data.

[0062] In yet another embodiment, the position unit **202** is configured to determine a planned position 'P_p' of the unmanned vehicle **102** according to the planned path data stored in the memory unit **216**.

[0063] In some embodiments, the position unit **202** is configured to determine the position of the unmanned vehicle **102** with respect to the position of other unmanned vehicles **102** in the system. Also in some other embodiments, the position unit **202** of the unmanned vehicle **102** is configured calculate its position with respect to a structure (i.e., a landmark) whose position is known. The structure may include, but not restricted to, a building, a tower, overhead cables, and so forth.

[0064] In some embodiments, the position unit **202** is configured to determine yaw parameters 'Y' for the current and/or planned path of the unmanned vehicle **102**. The yaw parameters may include, but not restricted to, a current yaw parameter 'Y_c' and a planned yaw parameter 'Y_p'. In some embodiments, the yaw parameters may be, but not restricted to, a yaw angle 'Y_a', a yaw velocity 'Y_v' and/or yaw rate 'Y_r' of the unmanned vehicle **102**, and the like.

[0065] In some other embodiments, the position unit **202** is configured to calculate longitudinal modes 'L' of the unmanned vehicle **102**. The longitudinal modes may include, but not restricted to, current longitudinal modes 'L_c' and planned longitudinal modes 'L_p'. The longitudinal modes of the unmanned vehicle **102** can be, but not restricted to, a pitch oscillation 'Pi'. In an exemplary scenario, the position unit **202** determines that a current pitch angle 'Pi_c' of the unmanned vehicle **102** is 8° during take-off. The current pitch angle 'Pi_c' is determined based on a current axis of the unmanned vehicle **102**.

[0066] In another embodiment, the position unit **202** is configured to calculate a roll 'R' of the unmanned vehicle **102**. The roll may be, but not restricted to, a current roll 'R_c' according to the current path and a planned roll 'R_p' of the unmanned vehicle **102** in accordance with the planned path.

[0067] Further, in some embodiments, the position unit **202** is configured to calculate a current speed 'S_c' of the unmanned vehicle **102** in accordance with the current position of the unmanned vehicle **102**. Also, the position unit **202** determines a planned speed 'S_p' of the unmanned vehicle **102** in accordance with the planned position on the planned path. Further, the position unit **202** can determine a relative speed 'S_{rc}' of the unmanned vehicle **102** relative to the other unmanned vehicles **102**.

[0068] In some other embodiments, the position unit **202** determines a current heading 'H_c' of the unmanned vehicle **102** in accordance with the current position of the unmanned vehicle **102**. Also, the position unit **202** calculates a planned heading 'H_p' of the unmanned vehicle **102** based on the planned path.

[0069] Further, the position unit **202** can be configured to calculate a current velocity 'V_c' of the unmanned vehicle **102** based on the current position the unmanned vehicle **102**.

Also, in some other embodiments, the position unit **202** determines a planned velocity 'V_p' in accordance with the planned path of the unmanned vehicle **102**.

[0070] In some embodiments, the control unit **204** communicates with the position unit **202** and receives the data related to the current position and the planned position of the unmanned vehicle **102**. Further, the control unit **204** can be configured to compare the current position and the planned position of the unmanned vehicle **102** and calculates a deviation from the planned path. In some embodiments, the control unit **204** determines a difference (hereinafter referred to as "the deviation") between the current position parameters and the planned position parameters.

[0071] In some other embodiments, the deviation can also occur due to environmental factors. As discussed, the environmental factor can include, but not restricted to, wind speed turbulence, weather, visibility, and the like. In an exemplary scenario, a hailstorm can cause the unmanned vehicle **102** to deviate from its planned path. In fact, embodiments of the present invention are intended to include or otherwise cover any number of the environmental factors that can cause the deviation from the planned path of the unmanned vehicle **102**.

[0072] Further, in alternate embodiments, the control unit **204** determines a threshold value 'T_h' for each of the parameters determined by the position unit **202**. The threshold value, 'T_h' can be based on the planned path parameters of the unmanned vehicle **102**. Further, in some embodiments, the threshold value 'T_h' can be predetermined by the base station **108** and included in the planned path data stored in a memory unit **216**. In some other alternate embodiment, the threshold value 'T_h' can be determined by the other companion unmanned vehicles **102**. In yet another embodiment, the control unit **204** of one of the plurality of unmanned vehicles **102** can set a threshold value 'T_h' for rest of the plurality of unmanned vehicles **102**.

[0073] In some other embodiments, the control unit **204** is configured to compare the determined deviation with the threshold value 'T_h'. The control unit **204** then determines whether there is a major deviation or minor deviation based on the comparison. In fact, embodiments of the disclosed subject matter are intended to include or otherwise cover any control unit, including known, related art, and/or later developed technologies that may be beneficial to determine the major or minor deviation of the unmanned vehicle **102** from planned path.

[0074] Further, in some other embodiments, the control unit **204** may check for more than one parameters to confirm deviation of the unmanned vehicle **102** from the planned path. For example, the control unit **204** gathers the data related to the current yaw angle 'Y_{ac}' of the unmanned vehicle **102**, and the planned yaw angle 'Y_{ap}' of the unmanned vehicle **102**. Thereafter the control unit **204** calculates the deviation, if the unmanned vehicle **102** is found deviated from its planned path, based on yaw parameters. Thereafter the control unit **204** can confirm the deviation by comparing current values and planned values of other parameters, such as pitch oscillations, roll, etc.

[0075] In an exemplary scenario, a controller **210** of the unmanned vehicle **102** determines a current altitude 'A_c' and a planned altitude 'A_p' of the unmanned vehicle **102**. The controller **210** further determines a deviation value 'ΔA' by comparing the current altitude 'A_c' and the planned altitude 'A_p'. Further, the controller **210** compares the deviation value 'ΔA' with a threshold value 'T_h' and is determined that there is a minor deviation and therefore, the unmanned vehicle **102** continues to follow the current path or moves back to the original planned path.

[0076] In yet another embodiment, the control unit **204** is configured to generate a new planned path based on the severity of deviation faced by the unmanned vehicle **102**. In the above exemplary scenario, if the deviation value 'ΔA' is greater than or equal to the threshold value 'T_h', then the deviation is said to be extensive or major and the unmanned vehicle **102** modifies the current path and follows a new planned path.

[0077] In another embodiment, the controller **210** of one of the plurality of unmanned vehicle **102** in a fleet decides the threshold value 'T_h' for rest of the plurality of unmanned vehicles **102** in the fleet. In an exemplary scenario, the controller **210** of one of the unmanned vehicle **102** in a fleet gathers the deviation value faced by the rest of the unmanned vehicles **102** in the fleet. The controller **210** then determines the greatest deviation value faced by one of the unmanned vehicle in the fleet. The controller **210**, compares the greatest deviation value with the common threshold value 'T_h'. The controller **210** may then determine whether the unmanned vehicles **102** of the fleet need to generate new planned paths, move on the current paths or move back to the original planned paths.

[0078] Further, the control unit **204** is configured to control the movement of the unmanned vehicle **102**. In an exemplary scenario, the control unit **204** determines the severity of deviation. If the deviation is slight or minor, then the control unit **204** controls the movements of the unmanned vehicle **102** such that the unmanned vehicle **102** moves along the current path or moves back to the original planned path. In another exemplary scenario, if the deviation is found to be major, then the control unit **204** plans a new path and controls the movement of the unmanned vehicle **102** such that the unmanned vehicle **102** moves along the new planned path.

[0079] In an exemplary scenario, the unmanned vehicle **102** may plan to move in a north direction ('H_p') from the base station **108** towards the destination to deliver an asset, with a speed 'S_p' of 40 miles per hour at an altitude 'A_p' of 1000 meters above the base station **108**. Unexpectedly, heavy winds force the unmanned vehicle **102** to veer off its planned path. The position unit **202** of the unmanned vehicle **102** detects a current heading 'H_c' of the unmanned vehicle **102** to be east with a current speed 'S_c' of 30 miles per hour at an altitude 'A_c' of 1200 meters above the base station **108**. Accordingly, the control unit **204** determines a major deviation from the planned path and regulates flight control components of the unmanned vehicle **102** such that the unmanned vehicle **102** moves towards the north direction. Also the control unit **204** regulates appropriate speed control components (e.g., a propeller) to increase the speed 'S' of unmanned vehicle **102**. Further, the control unit **204** changes the elevation of the unmanned vehicle **102** to change the altitude 'A' of the unmanned vehicle **102** to the planned altitude of 1000 meters above the base station **108**. The exemplary scenario, as described above, is for illustrative purposes, and is not intended to limit the scope of the present disclosure.

[0080] The threshold value 'T_h' determined by the control unit **204** can be changed depending upon the environmental factors. In some embodiments, the sensor unit **206** is con-

figured to sense the change in environmental conditions. In some embodiments, the sensor unit **206** can be, but not restricted to, a humidity sensor, a temperature sensor, a pressure sensor, and so forth. In other embodiments, the sensor unit **206** can communicate with weather satellites, communication towers, weather stations and the like to obtain data regarding the weather conditions. In fact, embodiments of the disclosed subject matter are intended to include or otherwise cover any sensor including known art, related art, and/or later developed technologies for sensing any change in environmental factors and sending a signal to other sub-units present in the exemplary system **100**.

[0081] Further, the sensor unit **206** transmits a signal to the control unit **204** stating one or more changes in current environmental conditions. The control unit **204** analyses and determines a new threshold value 'T_h' for the unmanned vehicle **102** based on the detected changes in environmental conditions. In an exemplary scenario, the sensor unit **206** senses a change in wind speed, following which the sensor unit **206** sends a signal to the control unit **204**. The control unit **204** then determines a new threshold value 'T_{h1}' for the unmanned vehicle **102**. Further, the control unit **204** determines the severity of deviation from the planned path by using the new determined threshold value 'T_{h1}'.

[0082] In yet another embodiment, the sensor unit **206** senses very adverse environmental conditions and then sends a signal to the control unit **204**. Further, the control unit **204** abandons the threshold value 'T_h' or lowers the threshold value 'T_h' during adverse environmental condition. For example, the sensor unit **206** senses very low visibility in the current path of the unmanned vehicle, then a signal is transmitted to the control unit **204** about the low visibility in the path. The control unit **204** then removes the threshold value 'T_h' because the unmanned vehicle **102** is more prone to deviation in low visibility conditions, and frequent planning and path modifications can be inefficient. In such cases, the unmanned vehicle **102** can determine a new planned path in order to avoid adverse environmental conditions.

[0083] In some other embodiments, the sensor unit **206** is configured to sense a temporary or transient environmental phenomenon, such as a gust of wind, an air pocket and so forth. The sensor unit **206** then communicates data regarding the temporary environment to the control unit **204**. Thereafter, the control unit **204** neglects the deviation caused by the temporary phenomenon and does not generate a new planned path. For example, the sensor unit **206** of the unmanned vehicle **102** senses a minor gust of wind. The sensor unit **206** informs the control unit **204** about the temporary environmental factor. Consequently, the control unit **204** does not generate a new planned path for the unmanned vehicle **102**. The unmanned vehicle **102** continues to move in the original planned path, after the temporary environmental phenomenon ends or the unmanned vehicle **102** has cleared the temporary environmental phenomenon.

[0084] Also, in some embodiments, the sensor unit **206** can sense the environmental factors in advance and transmit appropriate data to the control unit **204** that can include warnings about the impeding adverse environmental conditions in the planned path. The control unit **204** then can generate a new planned path and start following it without facing deviation due to impeding environmental factors.

[0085] The communication unit **208** can be configured to establish communication between the different units present in the unmanned vehicle **102**. In some embodiments, the communication unit **208** of the unmanned vehicle **102** in a fleet is configured to communicate with the other unmanned vehicles **102** in the fleet. In yet another embodiment, the communication unit **208** of the unmanned vehicle **102** can be configured to communicate with the base station **108**.

[0086] In some embodiments, the communication unit **208** of the unmanned vehicle **102** can be configured to receive the planned path data from the base station **108**. In yet another embodiment, the communication unit **208** is configured to receive the planned path data from the companion unmanned vehicles **102**. In some other embodiments the communication unit **208**, is configured to transmit a new planned path data to the base station **108** and/or to the companion unmanned vehicles **102**. Also, the communication unit **208** is configured to transmit feedback (e.g., telemetry data) received from the companion unmanned vehicles **102** to the base station **108**.

[0087] Further, the communication unit **208** can include communication methods that can include radio communications based on any frequency spectrum (e.g., Very High Frequency (VHF) or Ultra High Frequency (UHF)) and any supporting infrastructure (e.g., satellites, cell phone towers, etc.). In fact, embodiments of the present disclosed subject matter are intended to include or otherwise cover any type of techniques, including known, related art, and/or later developed technologies to receive and transmit the data to base station **108** and/or the other companion unmanned vehicles **102**.

[0088] Further, the receiver **214** is configured to receive signal parameters, from the base station **108** and/or the other companion unmanned vehicles **102**. The signal parameter can include, but not restricted to, signal strength, signal sensitivity, data transfer rate, phase of the unmanned vehicle **102** with respect to the base station **108** and/or the other companion unmanned vehicles **102**, and the like. The receiver **214** then communicates the current signal parameters to the control unit **204**. The control unit **204** determines the deviation by comparing the received signals with a predetermined signal threshold value 'T_h'. In an exemplary scenario, the unmanned vehicle **102** is in phase with the base station **108**. If the unmanned vehicle **102** goes out of phase, the unmanned vehicle **102** is considered to have deviated from the planned path. Subsequently, the control unit **204** can determine whether a new planned path is required or the current path is more efficient to reach the destination based on the factors discussed above.

[0089] In some embodiments, the receiver **214** can be, but not restricted to, a receive signal strength indicator (RSSI), a signal-to-noise detector, and the like. In fact, embodiments of the disclosed subject matter are intended to include or otherwise cover any type of techniques and/or receivers, including known, related art, and/or later developed technologies to receive signal parameters of the unmanned vehicle **102**.

[0090] Further, the memory unit **216** is configured to store the data related to the unmanned vehicle **102**. In some embodiments, the memory unit **216** is configured to store the planned path of the unmanned vehicle **102**. In yet other embodiments, the memory unit **216** is configured to store the current position of the unmanned vehicle **102** determined by the position unit **202**. The memory unit **216** can include any type of memory device, such as a Random Access Memory (RAM) or any other dynamic storage device. The memory

unit **216** can also store information including controller instructions to be executed by the controller **210**. In fact, embodiments of the disclosed subject matter are intended to include or otherwise cover any type of memory, including known, related art, and/or later developed technologies to store data related to the unmanned vehicle **102**.

[0091] In some embodiments, the control unit **204** can be further configured to compare the deviation n of the unmanned vehicle **102** from its planned path with a conformance threshold value 'T_{hc}'. The conformance threshold value 'T_{hc}' may be a predetermined value stored in the memory unit **216**. If the deviation is lesser than the conformance threshold value 'T_{hc}', control unit **204** may determine that the unmanned vehicle **102** is properly functioning without any hardware and/or software faults, and can travel along its path in a reliable manner. However, if the deviation is greater than or equal to the conformance threshold 'T_{hc}', the control unit **204** can determine that the unmanned vehicle **102** is non-conforming and may be unable to travel reliably along its planned path. The control unit **204** may flag the unmanned vehicle **102** as non-conforming and transmit, via the communication unit **208**, the non-conformance data to the companion unmanned vehicles **102** and/or the base station **108**. The unmanned vehicle **102** may be non-conforming due to hardware and/or software faults. The control unit **204** and/or the base station **108** may run diagnostics in order to determine such faults. Further, the base station **108** may assume control of the non-conforming unmanned vehicle **102** and can re-route the non-conforming unmanned vehicle **102** along a path that can impede or avoid collisions.

[0092] In other embodiments, any one of the companion unmanned vehicles **102** or the base station **108** can determine the deviation of the non-conforming unmanned vehicle **102** from its planned path and can appropriately flag the non-conforming vehicle **102**. The deviation of the non-conforming vehicle **102** can be determined by various methods, such as ranging tones, relative vehicle telemetry, and so forth.

[0093] Further, in some embodiments, the conformance threshold value 'T_{hc}' and the threshold value 'T_h' can be substantially equal. In other embodiments, the conformance threshold value 'T_{hc}' can be decided by the base station **108** and included in the planned path data stored in the memory unit **216**.

[0094] In various embodiments, the conformance threshold value 'T_{hc}' can correspond to various parameters, such as, but not limited to, distance, speed, altitude, yaw, roll, pitch, signal parameters, and so forth.

[0095] In further embodiments, the non-conforming unmanned vehicle **102** can be detected by its control unit **204**, the base station **108** and/or any one of the companion unmanned vehicles **102** by monitoring a deviation pattern of the non-conforming unmanned vehicle **102**. In case of technical faults, the deviation can be drastic and in an unexpected pattern. Therefore, non-conforming behavior can be detected in case of sudden and repeated deviations of large magnitudes from the planned path.

III. Operation of the Unmanned Vehicle

[0096] FIG. **3** is a flow chart of a procedure **300** for determining a planned path for an unmanned vehicle in accordance with the disclosed subject matter. In some embodiments, the unmanned vehicle **102** can be an unmanned aerial vehicle. This flowchart is merely provided for exemplary purposes, and embodiments are intended to include or otherwise cover any methods or procedures, including known, related art, and/or later developed technologies for determining a planned path for the unmanned vehicle **102**.

[0097] At step **302**, the controller **210** determines a current position of the unmanned vehicle **102** in accordance with a current path followed by the unmanned vehicle **102**. As discussed, the current position may be determined based on parameters such as, but not restricted to, vehicle trajectory parameters, signal parameters, environmental factors, and so forth.

[0098] At step **304**, the controller **210** determines a planned position of the unmanned vehicle **102** in accordance with a planned path. In some embodiments, the planned path can be received from the base station**108** and/or from other companion unmanned vehicles **102**. In some other embodiments, the planned path can be determined by the unmanned vehicle **102** itself. Further, the controller **210** determines parameters of the planned position. As discussed, the parameters of the planned position may be, but not restricted to, the vehicle trajectory parameters, the signal parameters, environmental factors and so forth.

[0099] Further, at step **306**, the controller **210** compares the current position parameters of the unmanned vehicle **102** with the planned position parameters of the unmanned vehicle **102**. Specifically, the controller **210** determines a difference between the current position parameters and the planned position parameters to determine a deviation of the unmanned vehicle **102** from the planned path. In some embodiments, the controller **210** determines a slight or minor deviation and/or extensive or major deviation on the basis of a comparison between the difference and the threshold value 'T_h'. In some other embodiments, the controller **210** also determines signal deviation by determining a difference between the signal parameters of the planned position and the signal parameters of the current position. Subsequently, the controller **210** compares the difference with the threshold value 'T_h'. Further, the controller generates and/or determines a new planned path for the unmanned vehicle **102** if the difference is greater than or equal to the threshold value 'T_h'.

[0100] Next, at step **308**, the controller **210** controls movements of the unmanned vehicle **102** to move along the new planned path.

[0101] FIG. **4** is a flowchart of a procedure **400** for determining the new planned path based on the deviation limits by using an unmanned vehicle or optionally manned vehicle in accordance with the disclosed subject matter. The flow chart is merely provided for exemplary purposes, and the embodiments are intended to include or otherwise cover any methods or procedures, including known, related art, and/or later developed technologies for determining a planned path based on deviation limits by an unmanned vehicle.

[0102] In accordance with the flow chart of FIG. **4**, at step **402**, the controller **210** determines a current position of the unmanned vehicle **102** in accordance with the current path followed by the unmanned vehicle **102**. Parameters to determine the current position of the unmanned vehicle **102** may include, but not restricted to, the vehicle trajectory parameters, the signal parameters, environmental factors and so forth.

[0103] At step **404**, the controller **210** determines a planned position of the unmanned vehicle **102** in accordance with the planned path. Further, the controller **210** determines parameters of the planned position. As discussed, the parameters of the planned position may be, but not restricted to, the vehicle trajectory parameters, the signal parameters, environmental factors and so forth.

[0104] At step **406**, the controller **210** compares the current position parameters of the unmanned vehicle **102** with the planned position parameters of the unmanned vehicle **102** to determine the deviation from the planned path. In some embodiments the controller **210** determines the slight or minor deviation, and extensive or major deviation on the basis of the comparison between the deviation and the predetermined threshold value 'T_h'. In some other embodiments, the controller **210** also determines the signal deviation by comparing the signal parameters of the planned position with the signal parameters of the current position of the unmanned vehicle **102**.

[0105] Next at step **408**, the controller **210** determines whether an extensive deviation is detected. The controller **210** compares the deviation with a threshold value 'T_h' in order to detect whether a minor or extensive deviation is detected. In case, the determined deviation is less than the threshold value 'T_h', then the deviation is a minor deviation. In case, it is determined that the unmanned vehicle **102** is slightly deviated from the planned path and planning a new path can be inefficient, then the controller **210** controls the movement of the unmanned vehicle **102** to follow the current path, and the procedure **400** proceeds to step **402**.

[0106] In case, the determined deviation is greater than or equal to the threshold value 'T_h', then the deviation is an extensive deviation and the procedure **400** proceeds towards step **410**. In case an extensive or major deviation is detected by the controller **210**, the procedure **400** proceeds to step **410**.

[0107] Next, at step **410**, the controller **210** generates a new planned path based on the parameters, such as, but not restricted to, the vehicle trajectory parameters, the environmental factors and the signal parameters, and the like. The generated planned path is more efficient than the planned path. The controller **210** of the unmanned vehicle **102** then controls the movement of the unmanned vehicle **102** and follows the new generated path.

[0108] Further, at step **412**, the controller **210** determines whether the unmanned vehicle **102** has reached the destination. In case, the unmanned vehicle **102** has reached its destination, then the procedure **400** concludes. In case, the unmanned vehicle **102** is still in the course of its journey and not yet reached the destination, then the procedure **400** moves to step **402** and the whole procedure **400** starts again.

IV. Exemplary Embodiments

[0109] An exemplary operation of the system **100** will be now described with reference to FIGS. **5**A, **5**B and **5**C. In an exemplary scenario **500**, three unmanned vehicles **102***a-c* start their journey from a source **516** to a destination **518**. After starting the journey, the unmanned vehicles **102***a-c* may communicate with each other and autonomously form the system **100**.

[0110] FIG. **5**A illustrates an exemplary scenario in which the unmanned vehicle **102***a-c* are following pre-planned paths **508***a-c*. In FIG. **5**A, a controller (not shown) of each of the unmanned vehicles **102***a-c* determines a current position **502***a-c* of each of the unmanned vehicles **102***a-c* respectively. The current positions **502***a-c* of the unmanned vehicle **102***a-c* can be determined by calculating various vehicle trajectory parameters, environmental factors and/or signal parameters of the unmanned vehicles **102***a-c*. For example, the controllers determine a current altitude 'A_c' and current heading 'H_c' of the unmanned vehicles **102***a-c*.

[0111] The controllers of the unmanned vehicles **102***a-c* also determine a planned position for each of the unmanned vehicles **102***a-c* respectively. Further, the controllers of the unmanned vehicles **102***a-c* determines vehicle trajectory parameters, environmental factor, signal parameters of the planned path of the unmanned vehicles **102***a-c* in order to determine the planned position for each of the unmanned vehicles **102***a-c*. For example, the controllers of the unmanned vehicles **102***a-c* determine the planned altitude 'A_p' and planned heading 'H_p' of the unmanned vehicles **102***a-c*.

[0112] In the exemplary scenario **500**, the unmanned vehicle **102***c* veer off its planned path due an obstacle **104** in its planned path **508***c*. The controller of the unmanned vehicle **102***c* compares the parameters of the current position **502***c* and the parameters of the planned position of the unmanned vehicle **102***c*. In addition, the controller calculates the difference between the current position **502***c* and the planned position of the unmanned vehicle **102***c*, such that the difference value can be termed as a deviation value **504**. For example, a current altitude 'A_c' is **1000** meters of the unmanned vehicle **102***c*, while the planned altitude 'A_p' of the unmanned vehicle **102***c* is 900 meters. The controller compares the current altitude 'A_c' and the planned altitude 'A_p' and determines a deviation of 100 meters in the altitude 'A' of the unmanned vehicle **102***c*.

[0113] The controller further determines a threshold value 'T_h' for the deviation **504** of the unmanned vehicle **102***c* from the planned path by analyzing the environmental factors. As discussed, a sensor unit (not shown) of the unmanned vehicle **102***c* detects the current environmental conditions and based on the detected conditions, the controller determines the threshold value 'T_h'. Further, the controller of the unmanned vehicle **102***c* communicates the determined threshold value 'T_h' to the companion unmanned vehicles **102***a-b*. Thereafter, the controller of the unmanned vehicle **102***c* compares the deviation **504** and the determined threshold value 'T_h'. Based on the comparison between the deviation **504** and the determines threshold value 'T_h', it is determined that there is a minor deviation from the planned path **508***c*, and therefore, the unmanned vehicle **102***c* continues to move along the deviated path **512**.

[0114] In some other exemplary scenario, the unmanned vehicle **102***c* can unexpectedly deviate from its planned path **508***c*. In an embodiment, the unexpected deviation can be determined by the other unmanned vehicles **102***a-b* in the fleet. In alternative embodiments, the control unit **204** and/or the base station **108** can determine the unexpected deviation. If the deviation value **504** is greater than or equal to the conformance threshold value 'T_{hc}', the unmanned vehicle **102***c* can be flagged as a non-conforming unmanned vehicle and the other unmanned vehicles **102***a-b* in the fleet may ignore the calculations, if any, made by the unmanned vehicle **102***c*. In various embodiments, the base station **108**, the control unit **204** of the unmanned vehicle **102***c* and/or the other unmanned vehicles **102***a-b* may flag the unmanned vehicle **102***c* as the non-conforming unmanned vehicle.

Also, if the unmanned vehicle **102***c* is declared as the non-conforming unmanned vehicle, the base station **108** can assume control and may re-route the unmanned vehicle **102***c* along a safe path in order to avoid any collisions. Moreover, the control unit **204** may run diagnostics in order to determine any hardware and/or software faults that can cause the non-conforming behavior of the unmanned vehicle **102***c*. The results of the diagnostics may be shared with the base station **108**.

[0115] In some embodiments, the base station **108**, the control unit **204** of the unmanned vehicle **102***c* and/or the other unmanned vehicles **102***a-b* may monitor a deviation pattern of the unmanned vehicle **102***c* and can determine that the unmanned vehicle **102***c* is a non-conforming vehicle in case of repeated and unexpected deviations from the planned path in a given time period. FIG. **5**B illustrates an exemplary scenario **500**B in which unmanned vehicles **102**a-c are following their respective planned paths **508***a-c* in accordance with the disclosed subject matter. As discussed, the controller of the each of the unmanned vehicles **102***a-c* determines their respective current position **502***a-c*, and planned positions. The controller of the unmanned vehicle **102***c* determines the threshold value 'T_h' for the unmanned vehicle **102***c*.

[0116] In the exemplary scenario **500**B, the unmanned vehicle **102***c* veer off its planned path due to the obstacle **104** in its planned path **508***c*. The controller of the unmanned vehicle **102***c* compares parameters of the current position **502***a-c*, with the parameters of the planned position in order to determine a deviation of the unmanned vehicle **102***c* from its planned path **508***c*. For example, the control controller of the unmanned vehicle **102***c* calculates a difference between the current altitude 'A_c' and the planned Altitude 'A_p' of the unmanned vehicle **102***c* and then calculates the deviation value **504** for the unmanned vehicle **102***c*. Further, the controller compares the calculated deviation value **504** with the determined threshold value 'T_h'. The controller further determines that the deviation value **504** is greater than the threshold value 'T_h', and therefore there is an extensive deviation from the planned path **508***c*. The controller of the unmanned vehicle **102***c* then generates a new planned path **514***c* for the unmanned vehicle **102***c*.

[0117] Further, the controller of the unmanned vehicle **102***c* controls movement of the unmanned vehicle **102***c* and follows the new planned path **514** to reach the destination **518**. The controller also changes the trajectory parameters such as, an altitude 'A', a heading 'H', a speed 'S', a yaw, roll, pitch, and the like, of the unmanned vehicle **102***c* such that the unmanned vehicle **102***c* follows the new planned path **514**. Also, the controller of the unmanned vehicle **102***c* communicates the new planned path **514** to the companion unmanned vehicles **102***a-b*.

[0118] Further, the other unmanned vehicles **102***a-b* in the fleet can verify that the deviation value **504** is less than the conforming threshold value 'T_{hc}'. If the deviation value **504** is less than the conforming threshold value 'T_{hc}', then the other unmanned vehicles **102***a-b* negotiate their paths accordingly and generate new planned paths **514***a* and **514***b* similar to the new planned path **514***c*, as shown in the FIG. **5**B. In other embodiments, the base station **108** can compare the deviation value **504** with the conforming threshold value 'T_{hc}' and verify that the unmanned vehicle **102***c* is behaving reliably. Based on the verification by the base station **108**, the other unmanned vehicles **102***a-b* negotiate their paths accordingly and generate the new planned paths **514***a* and **514***b* similar to the new planned path **514***c*, as shown in the FIG. **5**B.

[0119] FIG. **5**C illustrates an exemplary scenario **500**C illustrating unmanned vehicles **102***a-c* following planned paths **508***a-c*, in accordance with the disclosed subject matter. A sensor unit (not shown) of the unmanned vehicle **102***c* determines a storm **522** in the planned path **508***c*. The sensor unit then sends a signal to a control unit (not shown) of the unmanned vehicle **102***c*, to provide a warning about the storm **522** in the planned path **508***c*. The storm **522** can cause deviations from the planned path **508***c*, and therefore, to avoid the unnecessary deviation, the controller of the unmanned vehicle **102***c* generates a new planned path **520**. The controller further controls the movement of the unmanned vehicle **102***c* to follow the new generated planned path **520**.

V. Exemplary Computer System

[0120] FIG. **6** illustrates a computer system **600** upon which an embodiment of the invention may be implemented. Various components of the unmanned vehicle **102** including the controller **210** and the control unit **204** may be implemented by the computer system **600**. Although, the computer system **600** is depicted with respect to a particular device or equipment, it is contemplated that other devices or equipment (e.g., network elements, servers, etc.) within FIG. **6** can deploy the illustrated hardware and components of the computer system **600**. The computer system **600** is programmed (e.g., via computer program code or instructions) to detect deviation from the planned path by using one or more unmanned vehicles **102** described herein and includes a communication mechanism such as a bus **602** for passing information between other internal and external components of the computer system **600**. Information (also called data) is represented as a physical expression of a measurable phenomenon, typically electric voltages, but including, in other embodiments, such phenomena as magnetic, electromagnetic, pressure, chemical, biological, molecular, atomic, sub-atomic and quantum interactions. For example, north and south magnetic fields, or a zero and non-zero electric voltage, represent two states (0, 1) of a binary digit (bit). Other phenomena can represent digits of a higher base. A superposition of multiple simultaneous quantum states before measurement represents a quantum bit (qubit). A sequence of one or more digits constitutes digital data that is used to represent a number or code for a character. In some embodiments, information called analog data is represented by a near continuum of measurable values within a particular range. The computer system **600**, or a portion thereof, constitutes a means for performing one or more steps for detecting deviation from the planned path by using one or more unmanned vehicles **102**.

[0121] A bus **602** includes one or more parallel conductors of information so that information is transferred quickly among devices coupled to the bus **602**. One or more processors **604** for processing information are coupled with the bus **602**.

[0122] The processor (or multiple processors) **604** performs a set of operations on information as specified by computer program code related to detect the deviation from the planned path by using one or more unmanned vehicles **102**. The computer program code is a set of instructions or statements providing instructions for the operation of the

processor **604** and/or the computer system **600** to perform specified functions. The code, for example, may be written in a computer programming language that is compiled into a native instruction set of the processor **604**. The code may also be written directly using the native instruction set (e.g., machine language). The set of operations include bringing information in from the bus **602** and placing information on the bus **602**. The set of operations also typically include comparing two or more units of information, shifting positions of units of information, and combining two or more units of information, such as by addition or multiplication or logical operations like OR, exclusive OR (XOR), and. Each operation of the set of operations that can be performed by the processor is represented to the processor by information called instructions, such as an operation code of one or more digits. A sequence of operations to be executed by the processor **604**, such as a sequence of operation codes, constitute processor instructions, also called computer system instructions or, simply, computer instructions. The processors **604** may be implemented as mechanical, electrical, magnetic, optical, chemical, or quantum components, among others, alone or in combination.

[0123] The computer system **600** also includes a memory **606** coupled to the bus **602**. The memory **606**, such as a Random Access Memory (RAM) or any other dynamic storage device, stores information including processor instructions for storing information and instructions to be executed by the processor **604**. The dynamic memory **606** allows information stored therein to be changed by the computer system **600**. RAM allows a unit of information stored at a location called a memory address to be stored and retrieved independently of information at neighboring addresses. The memory **606** is also used by the processor **604** to store temporary values during execution of processor instructions. The computer system **600** also includes a Read Only Memory (ROM) or any other static storage device coupled to the bus **602** for storing static information, including instructions, that is not changed by the computer system **600**. Some memory is composed of volatile storage that loses the information stored thereon when power is lost. Also coupled to the bus **602** is a non-volatile (persistent) storage device **608**, such as a magnetic disk, a solid state disk, optical disk or flash card, for storing information, including instructions, that persists even when the computer system **600** is turned off or otherwise loses power.

[0124] Information, including instructions for detecting deviation from the planned by using one or more unmanned vehicles **102** is provided to the bus **602** for use by the processor **604** from an external input device **610**, such as a keyboard containing alphanumeric keys operated by a human user, a microphone, an Infrared (IR) remote control, a joystick, a game pad, a stylus pen, a touch screen, or a sensor. The sensor detects conditions in its vicinity and transforms those detections into physical expression compatible with the measurable phenomenon used to represent information in the computer system **600**. Other external devices coupled to the bus **602**, used primarily for interacting with humans, include a display **612**, such as a Cathode Ray Tube (CRT), a Liquid Crystal Display (LCD), a Light Emitting Diode (LED) display, an organic LED (OLED) display, active matrix display, Electrophoretic Display (EPD), a plasma screen, or a printer for presenting text or images, and a pointing device **616**, such as a mouse, a trackball, cursor direction keys, or a motion sensor, for controlling a position of a small cursor image presented on the display **612** and issuing commands associated with graphical elements presented on the display **612**, and one or more camera sensors **614** for capturing, recording and causing to store one or more still and/or moving images (e.g., videos, movies, etc.) which also may comprise audio recordings. Further, the display **612** may be a touch enabled display such as capacitive or resistive screen. In some embodiments, for example, in embodiments in which the computer system **600** performs all functions automatically without human input, one or more of the external input device **610**, and the display device **612** may be omitted.

[0125] In the illustrated embodiment, special purpose hardware, such as an ASIC **616**, is coupled to the bus **602**. The special purpose hardware is configured to perform operations not performed by the processor **604** quickly enough for special purposes. Examples of ASICs include graphics accelerator cards for generating images for the display **612**, cryptographic boards for encrypting and decrypting messages sent over a network, speech recognition, and interfaces to special external devices, such as robotic arms and medical scanning equipment that repeatedly perform some complex sequence of operations that are more efficiently implemented in hardware.

[0126] The computer system **600** also includes one or more instances of a communication interface **618** coupled to the bus **602**. The communication interface **618** provides a one-way or two-way communication coupling to a variety of external devices that operate with their own processors, such as printers, scanners and external disks. In general, the coupling is with a network link **620** that is connected to a local network **622** to which a variety of external devices with their own processors are connected. For example, the communication interface **618** may be a parallel port or a serial port or a Universal Serial Bus (USB) port on a personal computer. In some embodiments, the communication interface **618** is an Integrated Services Digital Network (ISDN) card, a Digital Subscriber Line (DSL) card, or a telephone modem that provides an information communication connection to a corresponding type of a telephone line. In some embodiments, the communication interface **618** is a cable modem that converts signals on the bus **602** into signals for a communication connection over a coaxial cable or into optical signals for a communication connection over a fiber optic cable. As another example, the communications interface **618** may be a Local Area Network (LAN) card to provide a data communication connection to a compatible LAN, such as Ethernet or an Asynchronous Transfer Mode (ATM) network. In one embodiment, wireless links may also be implemented. For wireless links, the communication interface **618** sends or receives or both sends and receives electrical, acoustic or electromagnetic signals, including infrared and optical signals that carry information streams, such as digital data. For example, in wireless handheld devices, such as mobile telephones like cell phones, the communication interface **618** includes a radio band electromagnetic transmitter and receiver called a radio transceiver. In certain embodiments, the communication interface **618** enables connection to the communication network **106** for detecting deviation from the planned by using one or more unmanned vehicles **102**. Further, the communication interface **618** can include peripheral interface devices, such as a thunderbolt interface, a Personal Computer Memory Card International Association (PCMCIA) interface, etc.

Although a single communication interface **618** is depicted, multiple communication interfaces can also be employed.

[0127] The term "computer-readable medium" as used herein refers to any medium that participates in providing information to the processor **604**, including instructions for execution. Such a medium may take many forms, including, but not limited to, computer-readable storage medium (e.g., non-volatile media, volatile media), and transmission media. Non-transitory media, such as non-volatile media, include, for example, optical or magnetic disks, such as the storage device **608**. Volatile media include, for example, the dynamic memory **606**. Transmission media include, for example, twisted pair cables, coaxial cables, copper wire, fiber optic cables, and carrier waves that travel through space without wires or cables, such as acoustic waves, optical or electromagnetic waves, including radio, optical and infrared waves. Signals include man-made transient variations in amplitude, frequency, phase, polarization or other physical properties transmitted through the transmission media. Common forms of computer-readable media include, for example, a floppy disk, a flexible disk, hard disk, magnetic tape, any other magnetic medium, a USB flash drive, a Blu-ray disk, a CD-ROM, CDRW, DVD, any other optical medium, punch cards, paper tape, optical mark sheets, any other physical medium with patterns of holes or other optically recognizable indicia, a RAM, a PROM, an EPROM, a FLASH-EPROM, an EEPROM, a flash memory, any other memory chip or cartridge, a carrier wave, or any other medium from which a computer can read. The term computer-readable storage medium is used herein to refer to any computer-readable medium except transmission media.

[0128] Logic encoded in one or more tangible media includes one or both of processor instructions on a computer-readable storage media and special purpose hardware, such as ASIC **616**.

[0129] The network link **620** typically provides information communication using transmission media through one or more networks to other devices that use or process the information. For example, the network link **620** may provide a connection through the local network **622** to a host computer **624** or to ISP equipment operated by an Internet Service Provider (ISP).

[0130] A computer called a server host **626**, connected to the Internet, hosts a process that provides a service in response to information received over the Internet. For example, the server hosts **626** hosts a process that provides information representing video data for presentation at the display **612**. It is contemplated that the components of the computer system **600** can be deployed in various configurations within other computer systems, e.g., the host **624** and the server **626**.

[0131] At least some embodiments of the invention are related to the use of the computer system **600** for implementing some or all of the techniques described herein. According to one embodiment of the invention, those techniques are performed by the computer system **600** in response to the processor **604** executing one or more sequences of one or more processor instructions contained in the memory **606**. Such instructions, also called computer instructions, software and program code, may be read into the memory **606** from another computer-readable medium such as the storage device **608** or the network link **620**. Execution of the sequences of instructions contained in the memory **606** causes the processor **604** to perform one or more of the method steps described herein. In alternative embodiments, hardware, such as the ASIC **616**, may be used in place of or in combination with software to implement the invention. Thus, embodiments of the invention are not limited to any specific combination of hardware and software, unless otherwise explicitly stated herein.

[0132] Various forms of computer readable media may be involved in carrying one or more sequence of instructions or data or both to the processor **604** for execution. For example, instructions and data may initially be carried on a magnetic disk of a remote computer such as the host **624**. The remote computer loads the instructions and data into its dynamic memory and sends the instructions and data over a telephone line using a modem. A modem local to the computer system **600** receives the instructions and data on a telephone line and uses an infra-red transmitter to convert the instructions and data to a signal on an infra-red carrier wave serving as the network link **620**. An infrared detector serving as the communication interface **618** receives the instructions and data carried in the infrared signal and places information representing the instructions and data onto the bus **602**. The bus **602** carries the information to the memory **606** from which the processor **604** retrieves and executes the instructions using some of the data sent with the instructions. The instructions and data received in the memory **606** may optionally be stored on the storage device **608**, either before or after execution by the processor **604**.

VI. Alternative Embodiments

[0133] While certain embodiments of the invention are described above, and FIGS. **1-6** disclose the best mode for practicing the various inventive aspects, it should be understood that the invention can be embodied and configured in many different ways without departing from the spirit and scope of the invention.

[0134] For example, embodiments are disclosed above in the context of an unmanned vehicle. However, embodiments are intended to include or otherwise cover any type of unmanned vehicle, including, an unmanned aerial vehicle, an unmanned terrestrial vehicle (for example, a driverless car), an unmanned terrestrial railed vehicle, an unmanned aquatic or oceanic vehicle, a drone, a gyrocopter, etc. In fact, embodiments are intended to include or otherwise cover configurations, including known, related art, and/or later developed technologies of the unmanned vehicle and/or optionally manned vehicle.

[0135] Embodiments are disclosed above in context of detecting the deviation from the planned path of the unmanned vehicle moving from point **1** to point **2**. However, embodiments are intended to cover any unmanned vehicle for inspection purposes, defense drones, surveillance purposes, recreational purposes, and so forth.

[0136] Exemplary embodiments are also intended to cover any method of detecting and flagging a non-conforming unmanned vehicle in a fleet based on a deviation of the non-conforming unmanned vehicle form its planned path. In fact, embodiments are intended to include or otherwise cover detection of any non-conforming behavior of an unmanned vehicle due to hardware and/or software faults.

[0137] Exemplary embodiments are intended to include or otherwise cover any type of obstacle and/or factor which can cause deviation in the planned path of the unmanned vehicle and/or optionally manned vehicle

[0138] Exemplary embodiments are intended to include or otherwise cover infrared obstacle detection technique for the detection of obstacles in the planned path of the unmanned vehicle.

[0139] Exemplary embodiments are also intended to cover any additional or alternative components of the unmanned vehicle disclosed above. Exemplary embodiments are further intended to cover omission of any component of the unmanned vehicle disclosed above.

[0140] Embodiments are intended to include or otherwise cover use of unmanned terrestrial vehicles for passenger transport, transportation of goods, and so forth.

[0141] Embodiments are intended to include or otherwise cover the determination of a new planned path for unmanned terrestrial vehicle. The reason can be beneficial because vehicles travelling on the roads are more prone to deviation due to other vehicles moving on the road.

[0142] Embodiments are intended to include or otherwise cover any technique involving the use of deviation limits to determine whether an unmanned vehicle or an optionally manned vehicle needs to follow a current path or generate a new path. This may avoid repeated calculation of new paths especially in case of minor deviations, thereby decreasing computational efforts and increasing efficiency.

[0143] Embodiments are intended to include or otherwise cover use of unmanned oceanic vehicles for underwater surveillance, helping persons stranded in the ocean, and so forth.

[0144] Embodiments are intended to include or otherwise cover use of unmanned space vehicles for space expeditions, carrying satellites to space, and so forth.

[0145] Embodiments are intended to include or otherwise cover use of sensed environmental conditions by the unmanned for accurately estimating weather conditions.

[0146] Embodiments are intended to include or otherwise cover use of signal parameters by the unmanned vehicle for accurately detecting communication faults.

[0147] Exemplary embodiments are also intended to include or otherwise cover a V-formation of the two or more unmanned vehicles (hereinafter referred to as a swarm or a fleet of unmanned vehicles), which can cause each of the unmanned vehicles to be well separated. The separation of the unmanned vehicles can allow each of the unmanned vehicles to individually determine the parameters of the current location and further, in determining the deviation causes. However, embodiments of the disclosed subject matter are intended to include or otherwise cover any type of formation that may be beneficial.

[0148] Embodiments are also intended to include or otherwise cover methods of manufacturing the unmanned vehicle and/or the optionally manned vehicle disclosed above. The methods of manufacturing include or otherwise cover processors and computer programs implemented by processors used to design various elements of the unmanned vehicle disclosed above.

[0149] Exemplary embodiments are intended to cover all software or computer programs capable of enabling processors to implement the above operations, designs and determinations. Exemplary embodiments are also intended to cover any and all currently known, related art or later developed non-transitory recording or storage mediums (such as a CD-ROM, DVD-ROM, hard drive, RAM, ROM, floppy disc, magnetic tape cassette, etc.) that record or store such software or computer programs. Exemplary embodiments are further intended to cover such software, computer programs, systems and/or processes provided through any other currently known, related art, or later developed medium (such as transitory mediums, carrier waves, etc.), usable for implementing the exemplary operations of the unmanned vehicles disclosed above.

[0150] While the subject matter has been described in detail with reference to exemplary embodiments thereof, it will be apparent to one skilled in the art that various changes can be made, and equivalents employed, without departing from the scope of the invention. All related art references discussed in the above Background section are hereby incorporated by reference in their entirety.

1. A method of controlling an unmanned vehicle operatively coupled to a controller, the method comprising:

determining, by the controller, a current position of the unmanned vehicle;

determining, by the controller, a planned position based on a planned path of the unmanned vehicle;

determining, by the controller, an actual deviation of the unmanned vehicle based on the planned position and the current position of the unmanned vehicle; and

controlling, by the controller, a movement of the unmanned vehicle such that the unmanned vehicle continues to move along the planned path without corrective action if the actual deviation of the unmanned vehicle is less than a predetermined threshold.

2. The method of claim **1**, wherein the deviation is equal to a difference between the planned position and the current position of the unmanned vehicle.

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

determining, by the controller, a new planned path for the unmanned vehicle if the deviation is greater than or equal to the predetermined threshold; and

controlling, by the controller, the movement of the unmanned vehicle such that the unmanned vehicle moves along the new planned path.

4. The method of claim **1**, further comprising communicating, by the controller, the new planned path to a companion unmanned vehicle.

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

detecting, by the controller, an ambient condition of the unmanned vehicle; and

modifying a value of the predetermined threshold based on the ambient condition.

6. The method of claim **5**, wherein the ambient condition is at least one of temperature, pressure, wind speed, visibility and turbulence.

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

receiving, by a receiver of the unmanned vehicle, a signal from a companion unmanned vehicle or a base station;

determining, by the controller, a signal deviation based on a parameter of the signal and a predetermined signal threshold; and

controlling, by the controller, the movement of the unmanned vehicle such that the unmanned vehicle moves along the planned path if the signal deviation is less than the predetermined signal threshold.

8. The method of claim **7**, further comprising:

determining, by the controller, a new planned path for the unmanned vehicle if the signal deviation is greater than or equal to the predetermined signal threshold; and

controlling, by the controller, the movement of the unmanned vehicle such that the unmanned vehicle moves along the new planned path.

9. The method of claim **7**, wherein the parameter of the signal is at least one of a signal strength, a signal sensitivity, a data transfer rate, and a phase of the signal.

10. An unmanned vehicle comprising:

a memory unit that is configured to store a planned path of the unmanned vehicle;

a position unit that is configured to determine a current position of the unmanned vehicle, the position unit further configured to determine a planned position of the unmanned vehicle based on the planned path data stored in the memory unit; and

a control unit disposed in communication with the position unit, the control unit configured to:

determine a actual deviation of the unmanned vehicle based on the planned position and the current position of the unmanned vehicle; and

control a movement of the unmanned vehicle such that the unmanned vehicle continues to move along the planned path without corrective action if the actual deviation of the unmanned vehicle is less than a predetermined threshold.

11. The unmanned vehicle of claim **10**, wherein the deviation is equal to a difference between the planned position and the current position of the unmanned vehicle.

12. The unmanned vehicle of claim **10**, wherein the control unit is further configured to:

determine a new planned path for the unmanned vehicle if the deviation is greater than or equal to the predetermined threshold; and

control the movement of the unmanned vehicle such that the unmanned vehicle moves along the new planned path.

13. The unmanned vehicle of claim **12**, further comprising a communication unit that is configured to communicate the new planned path to a companion unmanned vehicle.

14. The unmanned vehicle of claim **10**, further comprising a sensor unit that is configured to detect an ambient condition of the unmanned vehicle, wherein the control unit is further configured to modify a value of the predetermined threshold value based on the ambient condition.

15. The unmanned vehicle of claim **14**, wherein the ambient condition is at least one of temperature, pressure, wind speed, visibility and turbulence.

16. The unmanned vehicle of claim **10**, further comprising a receiver that is configured to receive a signal from a companion unmanned vehicle or a base station, wherein the control unit is further configured to:

determine a signal deviation based on a parameter of the signal and a predetermined signal threshold; and

control the movement of the unmanned vehicle such that the unmanned vehicle moves along the planned path if the signal deviation is less than the predetermined signal threshold.

17. The unmanned vehicle of claim **16**, wherein the parameter of the signal is at least one of a signal strength, a signal sensitivity, a data transfer rate, and a phase of the signal.

18. The unmanned vehicle of claim **10**, wherein the unmanned vehicle is one of an unmanned aerial vehicle, an unmanned terrestrial vehicle, an unmanned aquatic vehicle, an unmanned space vehicle and an optionally manned vehicle.

19. A system comprising a plurality of unmanned vehicles spaced from each other, each of the plurality of unmanned vehicles including:

a memory unit that is configured to store a planned path of the unmanned vehicle; and

a position unit that is configured to determine a current position of the unmanned vehicle, the position unit further configured to determine a planned position of the unmanned vehicle based on the planned path data stored in the memory unit; and

a control unit disposed in communication with the position unit, the controller configured to:

determine an actual deviation of at least one of the unmanned vehicles based on the planned position and the current position of the unmanned vehicle;

determine a new planned path for the unmanned vehicle if the deviation is greater than or equal to the predetermined threshold;

communicate the new planned path to other companion unmanned vehicles; and

control a movement of the unmanned vehicle such that the unmanned vehicle moves along the new planned path; and

control the movement of the unmanned vehicle such that the unmanned vehicle continues to move along the planned path without corrective action if the actual deviation of the unmanned vehicle is less than the predetermined threshold.

20. (canceled)

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