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(54) **UNMANNED VEHICLE, SYSTEM AND METHODS FOR COLLISION AVOIDANCE BETWEEN UNMANNED VEHICLE**

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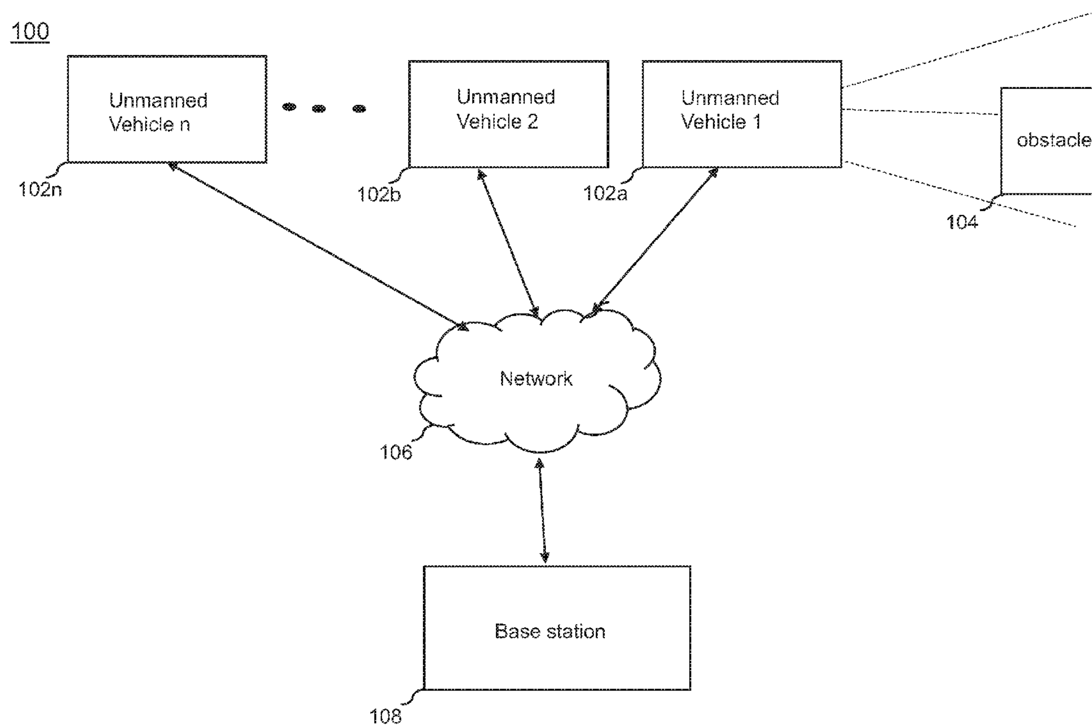
(57) **ABSTRACT**

Some embodiments are directed to an unmanned vehicle for use with a companion unmanned vehicle. The unmanned vehicle can include a satellite navigation unit that is configured to receive a satellite signal indicative of a current position of the unmanned vehicle. The unmanned vehicle can also include an inertial navigation unit that is configured to determine the current position of the unmanned vehicle. The unmanned vehicle can also include a control unit disposed in communication with the satellite navigation unit and the inertial navigation unit. The control unit is configured to determine a planned position of the unmanned vehicle based on the planned path, compare the current position determined by the inertial navigation unit with the planned position based on the planned path, and control the movement of the unmanned vehicle based on at least the comparison between the current position and the planned position.



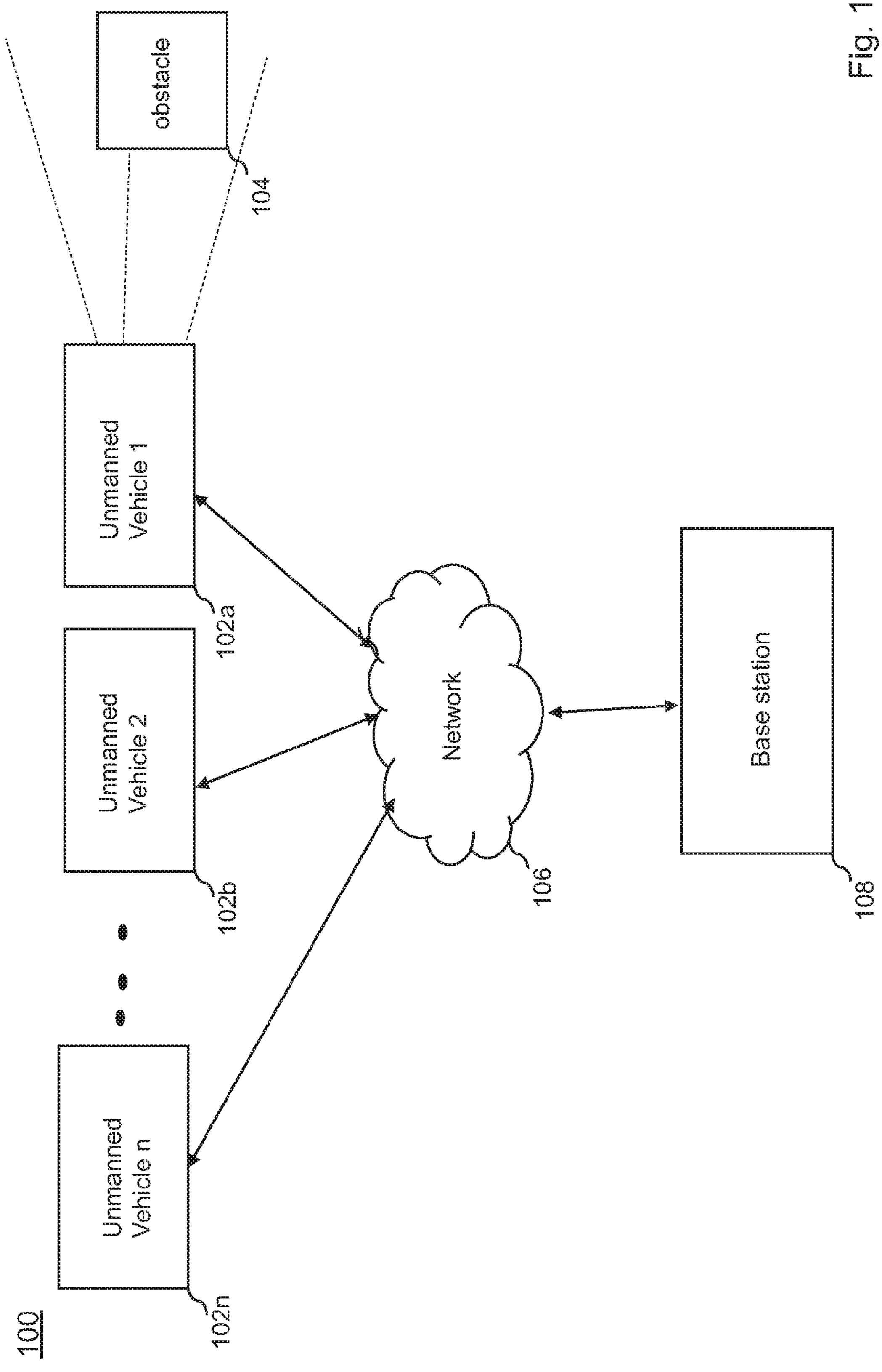

100
obstacle
104
Unmanned Vehicle 1
102a
Unmanned Vehicle 2
102b
Unmanned Vehicle n
102n
Network
106
Base station
108

Fig. 1

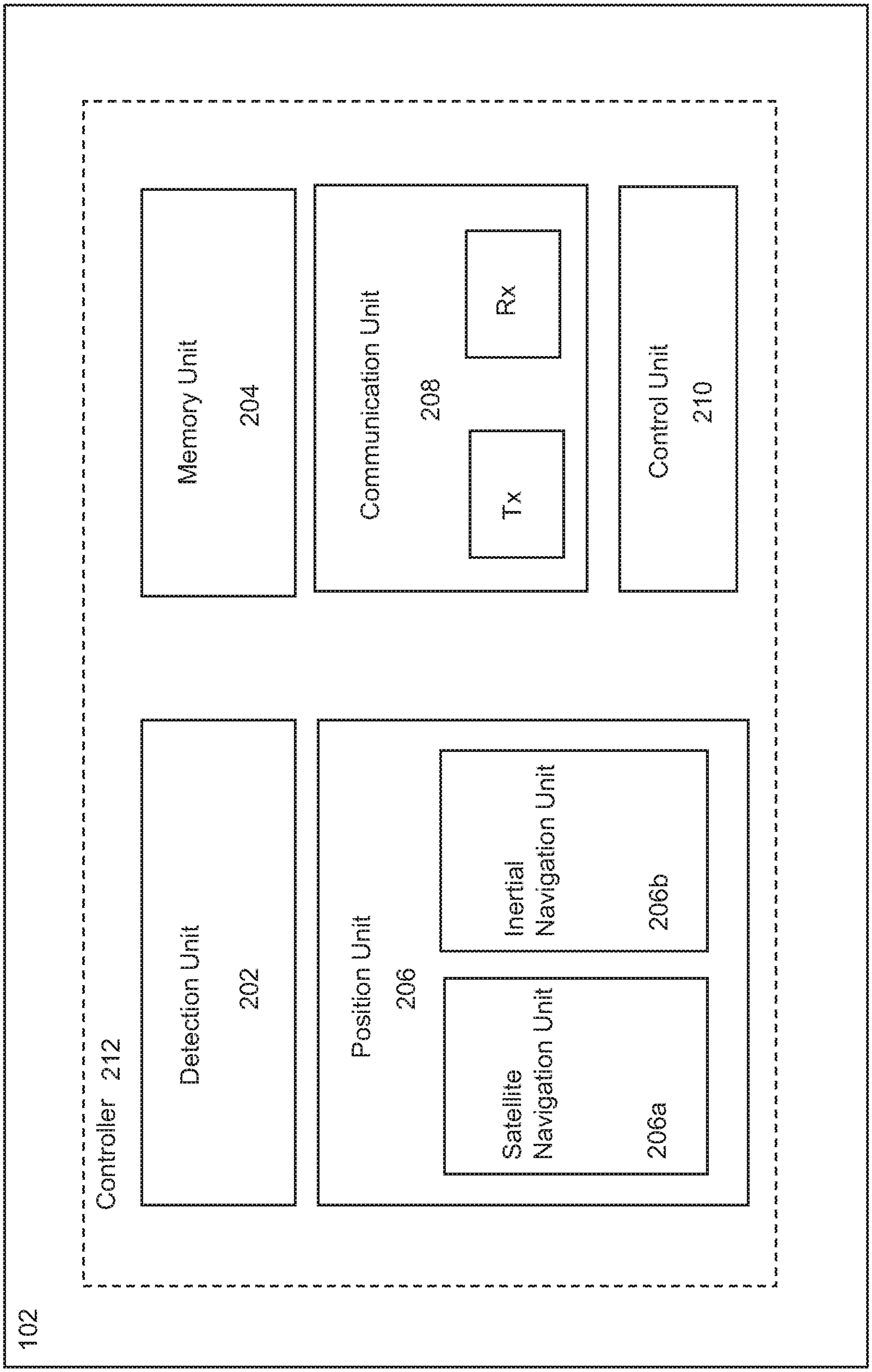

102
Controller 212
Detection Unit
202
Position Unit
206
Satellite
Navigation Unit
206a
Inertial
Navigation Unit
206b
Memory Unit
204
Communication Unit
208
Tx
Rx
Control Unit
210

Fig. 2

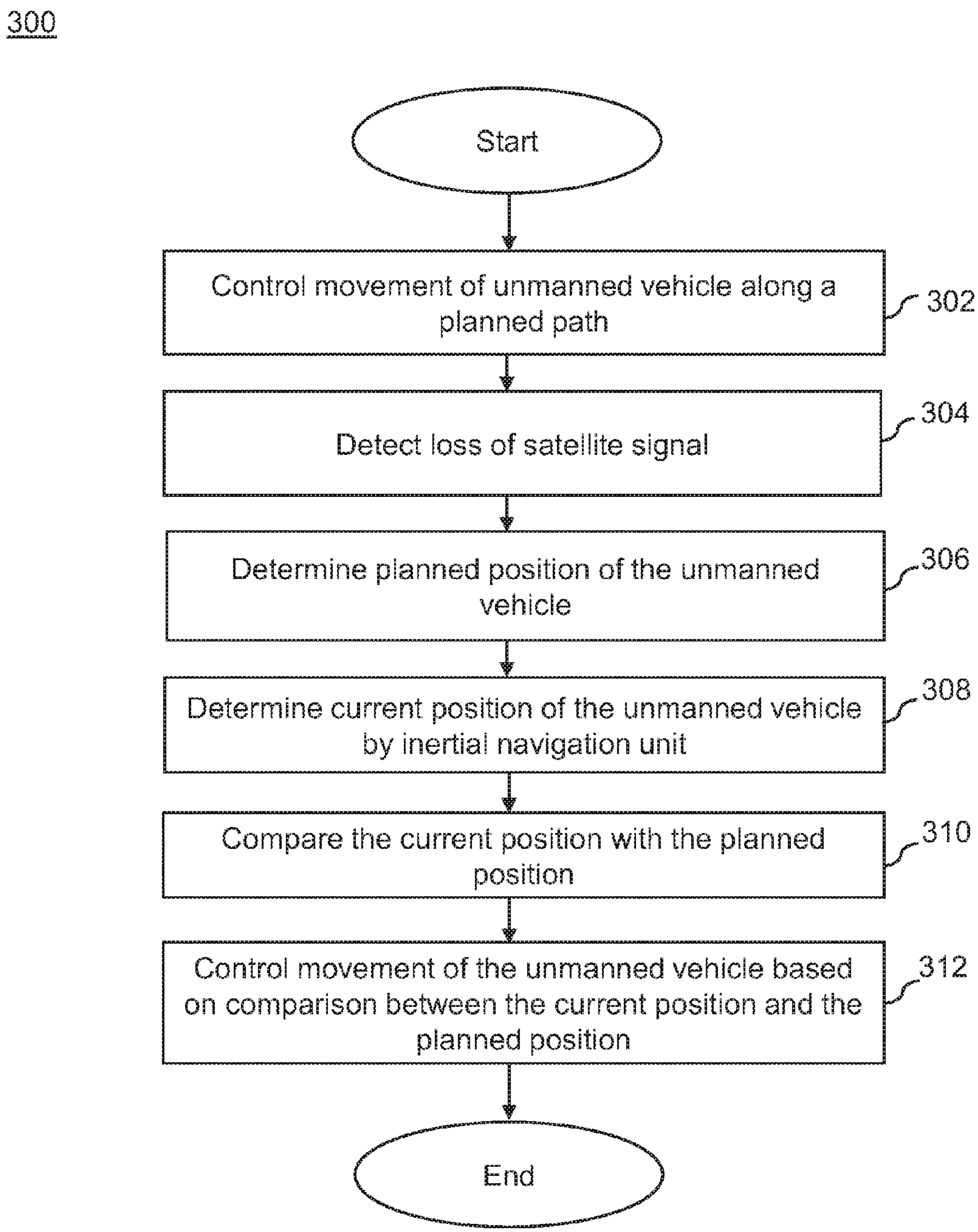

300
Start
Control movement of unmanned vehicle along a planned path
302
Detect loss of satellite signal
304
Determine planned position of the unmanned vehicle
306
Determine current position of the unmanned vehicle by inertial navigation unit
308
Compare the current position with the planned position
310
Control movement of the unmanned vehicle based on comparison between the current position and the planned position
312
End

FIG. 3

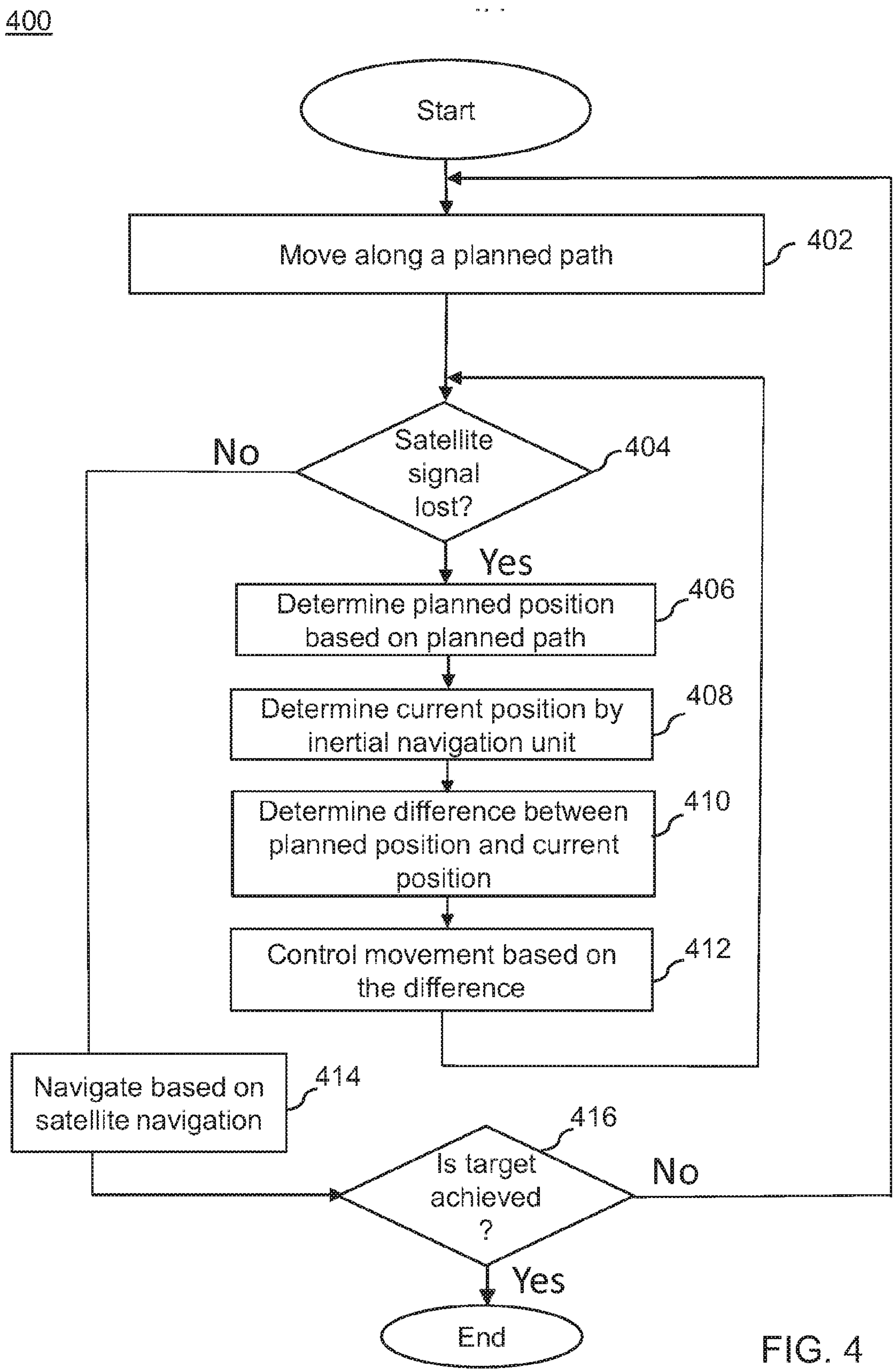
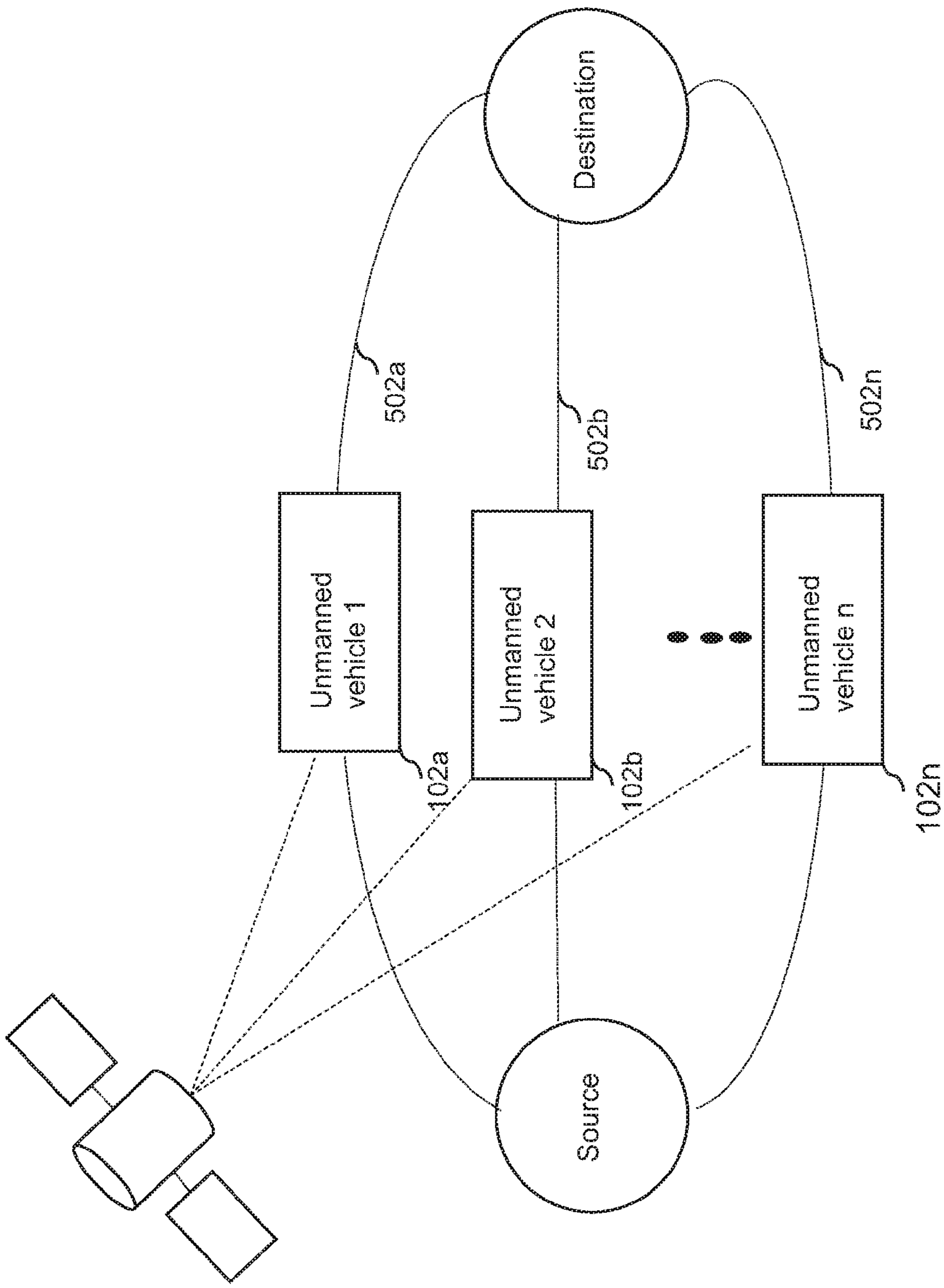

400
Start
Move along a planned path
402
Satellite signal lost?
404
No
Yes
Determine planned position based on planned path
406
Determine current position by inertial navigation unit
408
Determine difference between planned position and current position
410
Control movement based on the difference
412
Navigate based on satellite navigation
414
Is target achieved ?
416
No
Yes
End

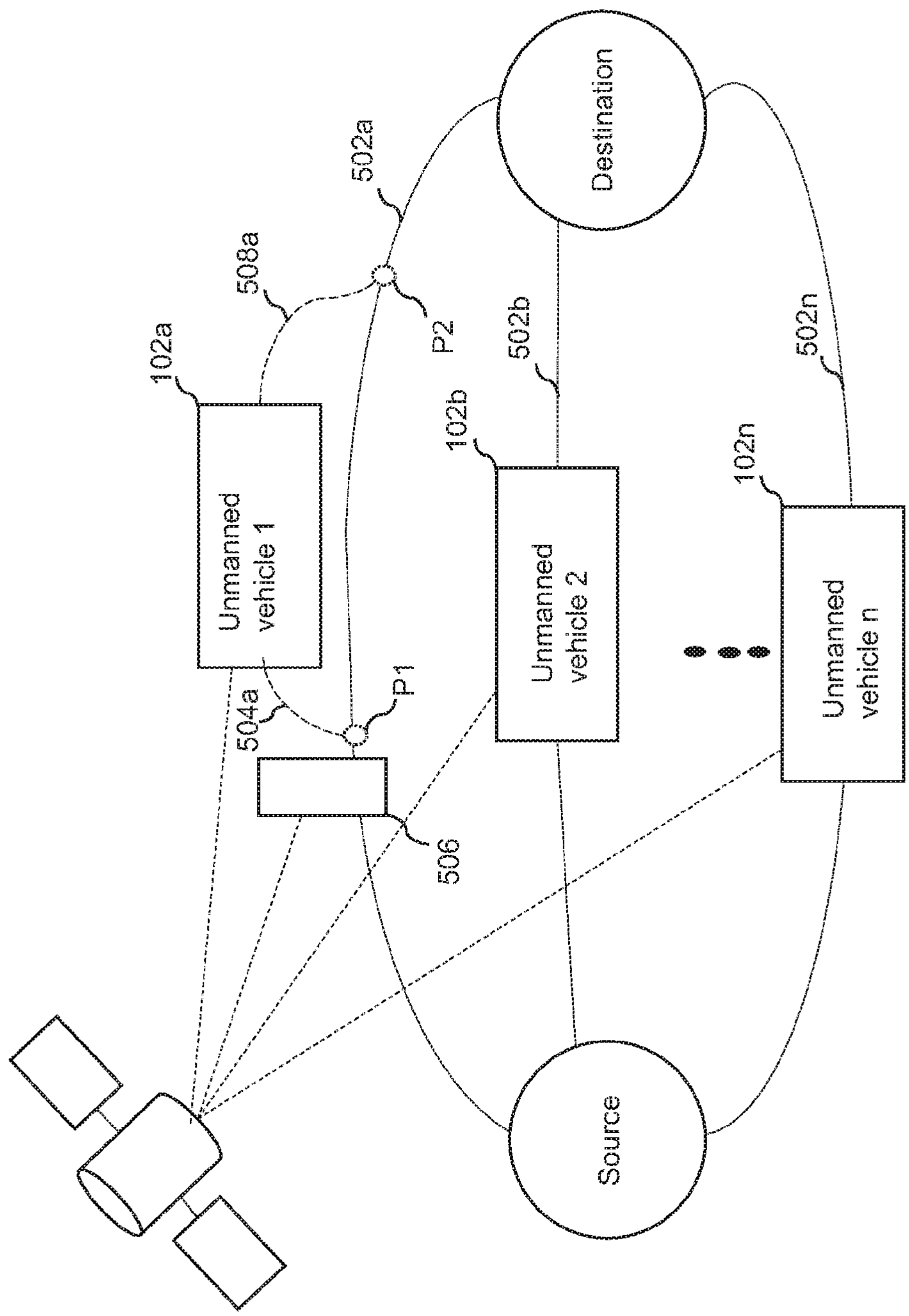
FIG. 4

Fig. 5A


Destination
Source
Unmanned vehicle 1
Unmanned vehicle 2
Unmanned vehicle n
502a
502b
502n
102a
102b
102n

500

Fig. 5B


Destination
502a
508a
P2
102a
Unmanned vehicle 1
502b
102b
Unmanned vehicle 2
502n
102n
Unmanned vehicle n
P1
504a
506
Source

500

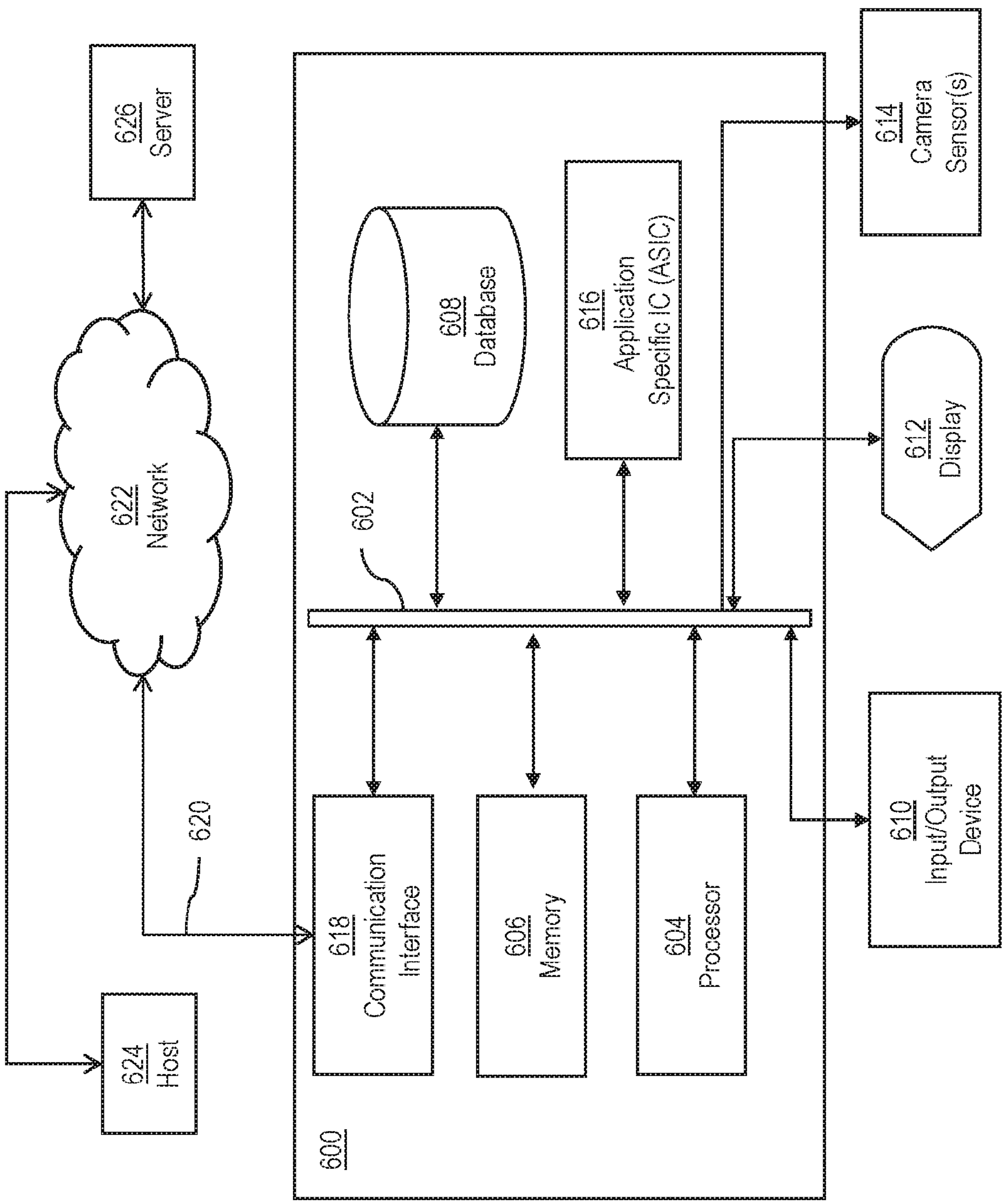

626 Server
622 Network
624 Host
620
602
608 Database
616 Application Specific IC (ASIC)
614 Camera Sensor(s)
612 Display
610 Input/Output Device
618 Communication Interface
606 Memory
604 Processor
600

FIG. 6

UNMANNED VEHICLE, SYSTEM AND METHODS FOR COLLISION AVOIDANCE BETWEEN UNMANNED VEHICLE

PRIORITY INFORMATION

[0001] 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

[0002] 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 avoiding collision among unmanned vehicles or optionally manned vehicles, and systems and methods for avoiding collision between unmanned vehicles or optionally manned vehicles, and obstacles.

[0003] An unmanned vehicle is a vehicle without a person on board, which is capable of sensing their surroundings and navigating 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.

[0004] Optionally manned vehicles can be operated with or without a person on board. 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 are vulnerable to collision with each other and/or with obstacles present in their paths. Unmanned vehicles may also unexpectedly veer off course due to the presence of obstacles or unpredictable environmental conditions. Further, fleets of two or more unmanned vehicles facing sudden changes in their environment are more likely to suffer from such collisions as each unmanned vehicle in the fleet is subject to similar environmental changes.

SUMMARY

[0006] Unmanned vehicles are in jeopardy of colliding with each other (vehicle to vehicle collisions) and/or with obstacles present in their operational environments. The obstacles can be, for example, buildings, antennas, terrain features, and the like. An unmanned terrestrial, aquatic or space vehicle may also suffer collisions with different obstacles, such as with trees, rocks, bodies of water, sand banks, coral, orbital debris, and so forth. One of the reasons for such collisions is lack of geographical information of the given obstacles. Further, unmanned vehicles can also veer off course due to unexpected environmental conditions, such as changes in wind patterns, rain, snow, avalanches etc.

[0007] Further, in case of a fleet of unmanned vehicles, the possibility of vehicle to vehicle collision can increase exponentially since each unmanned vehicle is subject to similar environmental changes. Possibility of collisions between the unmanned vehicles and obstacles also similarly increase.

[0008] Some related arts have tried to mitigate collisions among unmanned vehicle by relaying a planned path of a first unmanned vehicle to a second unmanned vehicle. However, the first unmanned vehicle or the second unmanned vehicle may deviate from the planned path due to unexpected environmental conditions. Therefore, any collision avoidance strategy based solely on planned path data may be inaccurate and can lead to collisions between the first and second unmanned vehicle.

[0009] Some related arts have tried to incorporate satellite navigation data (e.g., GPS data) of the first vehicle's location into information available to the second vehicle to accurately integrate the first vehicle's planned path with its current location. However, the GPS data may not be always available or may be partially inaccurate. For example, the first and second unmanned vehicles can be travelling in a region where GPS data is unavailable or intermittently available.

[0010] Optionally manned vehicles can face similar problems as described above with reference to unmanned vehicles. Specifically, optionally manned vehicles can suffer from collisions with each other or with obstacles during an unmanned mode of operation.

[0011] It may therefore be beneficial to provide an unmanned vehicle, a system, and a method of use, that address at least one of the above issues. For example, it may be beneficial to provide the unmanned vehicle with an inertial navigation unit as a backup that can help in navigating the unmanned vehicle in case of loss of satellite signal.

[0012] It may therefore be beneficial to provide an unmanned vehicle, a system, and a method of use, that address at least one of the above and/or other disadvantages. In, particular, it may be beneficial to provide the unmanned vehicle, a system and a method that combine a planned path of the unmanned vehicle and position data from an inertial navigation unit in order to navigate the unmanned vehicle during loss of satellite signal.

[0013] It may therefore be beneficial to provide an unmanned vehicle, a system, and method of use, 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 combine position data of a companion unmanned vehicle with position data from an inertial navigation unit in order to navigate the unmanned vehicle during loss of satellite signal.

[0014] Some embodiments are therefore directed to a method of controlling an unmanned vehicle having a satellite navigation unit and an inertial navigation unit. The unmanned vehicle is operatively coupled to a controller. The method can include controlling, by the controller, a movement of the unmanned vehicle such that the unmanned vehicle moves along a planned path; detecting, by the controller, a loss of a satellite signal at the satellite navigation unit; determining, by the controller, a planned position of the unmanned vehicle based on the planned path; determining, by the inertial navigation unit, a current position of the unmanned vehicle; comparing, by the controller, the current position determined by the inertial navigation unit with the planned position based on the planned path; and controlling, by the controller, a movement of the unmanned vehicle based on at least the comparison between the current position and the planned position.

[0015] Some other embodiments are directed to an unmanned vehicle. The unmanned vehicle can include a satellite navigation unit that is configured to receive a satellite signal indicative of a current position of the unmanned vehicle. The unmanned vehicle can also include an inertial navigation unit that is configured to determine the current position of the unmanned vehicle relative to an initial position. The unmanned vehicle can also include a memory unit that is configured to store a planned path of the unmanned vehicle. Further, the unmanned vehicle can also include a control unit disposed in communication with the satellite navigation unit, the inertial navigation unit and the memory unit. The control unit is configured to detect a loss of satellite signal at the satellite navigation unit; receive the current position of the unmanned vehicle from the inertial navigation unit; determine a planned position of the unmanned vehicle based on the planned path; compare the current position determined by the inertial navigation unit with the planned position based on the planned path; and control the movement of the unmanned vehicle based on at least the comparison between the current position and the planned position.

[0016] Yet other embodiments are directed to a system including unmanned vehicles, wherein each of the unmanned vehicles can include a satellite navigation unit that is configured to receive a satellite signal indicative of a current position of the unmanned vehicle. The system including the unmanned vehicles, wherein each of the unmanned vehicles can also include an inertial navigation unit that is configured to determine the current position of the unmanned vehicle relative to an initial position. The system including the unmanned vehicles, wherein each of the unmanned vehicles can also 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 vehicles can also include a communication unit disposed in communication with other unmanned vehicles, the communication unit being configured to receive a current position of each of the other unmanned vehicles. Further, the system including the unmanned vehicles, wherein each of the unmanned vehicles can also include a control unit disposed in communication with the satellite navigation unit, the inertial navigation unit, the memory unit and the communication unit. The control unit is configured to detect a loss of satellite signal at the satellite navigation unit; receive the current position of the unmanned vehicle from the inertial navigation unit; determine a planned position of the unmanned vehicle based on the planned path; receive the current position of each of the other unmanned vehicles; and control the movement of the unmanned vehicle based on at least the current position determined by the inertial navigation unit, the planned position based on the planned path, and the current position of each of the other unmanned vehicles.

[0017] As mentioned above, many current related art technologies fail to compute or transmit various aspects of information such as position, planned trajectory, electronic data, etc. in calculating their planned paths (or trajectories). This can become important in situations where communication with a ground or base station is encumbered or absent, although vehicles still need to re-calculate their prospective trajectories and possibly relay the new trajectories (e.g., ad-hoc) to other vehicles.

[0018] Some of the disclosed embodiments address this problem by employing a combination of calculated planned path trajectories, GPS information, ranging tone calculations, and importantly, the aforementioned inertial navigation technologies. The inertial navigation units can record changes in acceleration, velocity, altitude, etc. relative to a baseline communication loss starting position to calculate where a particular vehicle is in relation to the starting position. Moreover, this information could be transmitted directly to other neighboring vehicles such that each can collaborate re-calculated planned paths based solely on inertial navigation data.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] 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 way of example, and with reference to the accompanying drawings, in which:

[0020] FIG. **1** is an exemplary system of unmanned vehicles in accordance with the disclosed subject matter.

[0021] FIG. **2** illustrates components of the unmanned vehicle in accordance with the disclosed subject matter.

[0022] FIG. **3** is a flowchart of an exemplary procedure for controlling movement of unmanned vehicles according to disclosed subject matter.

[0023] FIG. **4** is a flowchart of an exemplary procedure for controlling movement of unmanned vehicle according to disclosed subject matter.

[0024] FIG. **5**A is a schematic of unmanned vehicles travelling along planned paths in accordance with disclosed subject matter.

[0025] FIG. **5**B is a schematic of one or more unmanned vehicles navigating with an inertial navigation unit in accordance with disclosed subject matter.

[0026] 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

[0027] A few inventive aspects of the disclosed embodiments are explained in detail below with reference to the various figures. Exemplary embodiments are described to illustrate the disclosed subject matter, not to limit its 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 the description that follows.

I. System of Unmanned Vehicles

[0028] FIG. **1** is an exemplary system **100** of unmanned vehicles in accordance with the disclosed subject matter.

[0029] FIG. **1** illustrates the system **100** that includes unmanned vehicles **102***a* to **102***n*, hereinafter referred to as an unmanned vehicle **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, etc. In fact, embodiments are intended to include or otherwise cover any type of unmanned aerial vehicle that may stay geostationary in the sky and also fly at a considerable height near and/or above an object to be inspected. The unmanned aerial vehicle **102** is merely provided for exemplary purposes, and the various inventive aspects are intended to be applied to any type of unmanned vehicle. In alternative embodiments, the system **100** can include one or more optionally manned vehicles.

[0030] In some embodiments, the unmanned vehicle **102** can be manually controlled by an operator present at a base station **108**. In some other embodiments, the unmanned vehicle **102** may be autonomously controlled based on a predetermined control strategy. In yet other embodiments, the unmanned vehicle **102** may be semi-autonomously controlled, which involves an operator entering and/or selecting one or more attributes and subsequent autonomous control of the unmanned vehicles **102** based on the 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**.

[0031] 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 fuel cell, a photovoltaic cell, a combustion engine, fossil fuel, solar energy, 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.

[0032] 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 used to control movements and/or orientation of the unmanned vehicle **102**.

[0033] 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. In some embodiments, the processor can be any suitable processing device configured to run and/or execute software that is either stored on the unmanned vehicle **102** or transmitted to the unmanned vehicle **102**. The processor can be configured to generate a planned path and/or re-plan an existing planned path in response to receiving a signal from an external communication device or another unmanned vehicle. In alternate embodiments, the processor can be, but not restricted to, a general purpose processor, a Field Programmable Gate Array (FPGA), an Application Specific Integrated Circuit (ASIC), a Digital Signal Processor (DSP), and/or the like. In fact, embodiments of the disclosed subject matter 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. 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.

[0034] In some embodiments, the system **100** including the unmanned vehicle **102***a* to **102***n* may be a fleet of unmanned vehicles that may execute an operation. The operation may involve transfer of payload from a position to another position, flights between two positions, tracking a target, surveillance and so forth. Each of the unmanned vehicle **102** in the system may be a companion unmanned vehicle of the other unmanned vehicles **102**.

[0035] In the exemplary system, each unmanned vehicle **102** has a planned path between positions, to optimize various parameters such as, but not restricted to, travel time, power requirements and so forth. For example, the unmanned vehicle **102** can be configured to travel from position "A" to position "B". The planned path for the unmanned vehicle **102** may be an optimal path between positions "A" and "B" in terms of travel time, power requirements, collision avoidance, jurisdictional requirements, stealth requirements, wind patterns etc. In alternate embodiments, the planned path can be segmented, such as a first planned path from position "A" to site 1(not shown), a second planned path from site 1 to site 2 (not shown), and a third planned path form site 2 back to point "A" (not shown). Moreover, if the mission is executed as planned, then the unmanned vehicle **102** travels along each of the planned paths in sequence. However, in case of unexpected events, the unmanned vehicle **102** goes off course due to various scenarios. In one exemplary scenario, the unmanned vehicle **102** may determine the planned position and the current position of the unmanned vehicle **102**, and the difference between the planned position and the current position. The difference between planned position and the current position is compared with a threshold value, which is based on various parameters such as, but not restricted to, position, distance, angular orientation, and the like. Further, based on the comparison between the threshold value and the calculated difference, the unmanned vehicle **102** determines if it has to modify the planned path or generate a new planned path in order to impede or avoid collisions and achieve the target. However, calculating a new planned path expends computational resources and time, and in case of a fleet, such as the system **100** illustrated in FIG. **1**, if the unmanned vehicle **102***a* re-calculates a new planned path, one or more of the companion unmanned vehicle **102***b* to **102***n* may also have to calculate a new planned path. Thus, it may beneficial for each of the unmanned vehicles **102** to follow its original planned path and, if necessary, make minor corrections in case the unmanned vehicle **102** goes off course from the planned path instead of recalculation of a new planned path.

[0036] In some embodiments, a base station **108** is configured to generate planned path for the unmanned vehicle **102** based on one or more parameters such as, but are not restricted to, a starting position, a destination, mission requirements (surveillance, tracking etc.), no-fly zones, fuel availability, and so forth. Further, the planned path is transmitted to each of the unmanned vehicles **102**. In further embodiments, the unmanned vehicle **102** can be configured to generate a new planned path when the unmanned vehicle **102** is required to diverge from its current planned path. The planned path can include a series of positions, speeds, altitudes, headings or orientations and so forth. Further each position may be linked to a corresponding speed, altitude, and orientation.

[0037] In alternate embodiments, the base station **108** transmits data required to generate the planned path for each of the unmanned vehicles **102** and each of the unmanned vehicles **102** generates their own planned paths based on the data provided by the base station **108**. Further, the unmanned vehicle **102***a* can transmit the planned path associated with it to the other unmanned vehicle **102***b* to **102***n*, in order to enable the other unmanned vehicles **102***b* to **102***n* to consider the planned path when generating their respective planned paths so as to enhance cooperation, and avoid or impede close encounters or collisions. Close encounter can include situations when a distance between two unmanned vehicles **102** are less than a safe distance.

[0038] In some embodiments, the unmanned vehicle **102** may generate a new planned path or modify its current planned path in case of various events or situations. For example, there may be a possibility of one or more unmanned vehicles **102** veering off course due to unforeseen circumstances such as, but are not restricted to, unpredictable wind patterns, rain, or other environmental factors. The unmanned vehicles **102** may also veer off course due to an obstacle **104**. In such situations, the vehicle may generate a new planned path or modify the original planned path so as to more effectively accomplish the mission requirements and/or enhance cooperation between the other unmanned vehicles **102***b* to **102***n*. In alternate embodiments, the unmanned vehicle **102** may re-calculate its planned path if there is a change in mission requirements or if certain mission objectives have been accomplished or are unnecessary.

[0039] The unmanned vehicle **102***a* can predict whether a close encounter or a potential collision based on the knowledge of its own planned path and planned path of the companion unmanned vehicles **102***b* to **102***n* in the system **100**. In some embodiments, the unmanned vehicle **102***a* compares its planned path with the planned paths of the companion unmanned vehicles **102***b* to **102***n* in order to determine the possibility of a close encounter or a collision. If the unmanned vehicle **102** does not detect a potential close encounter or a collision, it will continue to travel along its planned path. In some other embodiments, if the unmanned vehicle **102***a* detects a close encounter or collision, a corrective action can be taken which is not disruptive to the missions of the unmanned vehicle **102***a*. Further, only the unmanned vehicles **102***a* may need to adjust its planned path while and the companion unmanned vehicles **102***b* to **102***n* may continue on their respective planned paths.

[0040] In some embodiments, the unmanned vehicle **102** may make adjustments such as, but not restricted to, a temporary speed adjustment, a temporary altitude adjustment and a horizontal profile adjustment to return to the original planned path after veering off course. Additionally, in order to optimize cooperation between the unmanned vehicles **102**, the planned path data includes sufficient data for a recipient of the planned path data to determine the expected future position of all the unmanned vehicles **102** that transmitted the planned path data. In an embodiment, the data, which enables the determination of the expected future position of any one of the unmanned vehicle **102**, can include, but not restricted to, an absolute time at the start of the planned path, a flight time specified by the path, data to determine a speed profile of the path, data to determine an altitude profile of the path, and data to determine the horizontal profile of the path.

[0041] Further, in some embodiments, the unmanned vehicle **102** detects potential collision of the unmanned vehicle **102** with the obstacle **104**. The obstacle **104** can include, but not restricted to, buildings, antennas, terrain features, and so forth. In some other embodiments, the obstacle **104** can be, but not restricted to, trees, rocks, bodies of water, sand banks, coral or even orbital debris. In yet other embodiments, the obstacle **104** can be a mobile obstacle, such as an aircraft, a terrestrial vehicle, an aquatic vehicle, a bird, and so forth. In fact, embodiments of the disclosed subject matter are intended to include or otherwise cover any type of obstacle that can lie in the operational paths of the unmanned vehicle **102**.

[0042] Moreover, the unmanned vehicle **102** may use the position data to generate the planned path. The unmanned vehicle **102** may then send the position data, through a communication network **106**, to the base station **108**. In some embodiments, position data may include, but not restricted to, latitude, longitude, and altitude. In alternate embodiments, the unmanned vehicle **102** can use, but not restricted to, a navigation device, such as a satellite navigation unit, an inertial navigation unit, or other location sensing devices.

[0043] Each of the unmanned vehicle **102** may be further configured to communicate with the companion unmanned vehicles **102**. In some embodiments, the unmanned vehicle **102** may communicate with other companion unmanned vehicles **102** through, but not restricted to, a communication network such as the communication network **106** of the system **100**.

[0044] 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 rates for Global Evolution (EDGE), General Packet Radio Service (GPRS), Global System for Mobile Communications (GSM), Internet protocol Multimedia Subsystem (IMS), Universal Mobile Telecommunications System (UMTS) etc. In other 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 further 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 **106** includes a cellular telephone network configured to enable exchange of text or SMS messages.

[0045] Examples of the communication network **106** may include, but are not limited to, Ad Hoc P2P, 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**.

[0046] The base station **108** can be a fixed base station or a mobile base station. In some other embodiments, the mobile base station 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, including known, related art, and/or later developed technologies to communicate with other unmanned vehicles **102**.

[0047] The functioning of the unmanned vehicle **102** is described in more detail below in conjunction with FIG. **2**.

II. Functioning of the Unmanned Vehicle

[0048] FIG. **2** illustrates components of one or more of the unmanned vehicles **102**, in accordance with the disclosed subject matter.

[0049] In some embodiments, the unmanned vehicle **102** can include, a detection unit **202**, a memory unit **204**, a position unit **206**, a communication unit **208** and, a control unit **210**. In fact, embodiments of the disclosed subject matter are intended to include or otherwise cover any number of components in the unmanned vehicle **102** including known, related art, and/or later developed technologies to control the movement of the unmanned vehicle **102** in a planned way.

[0050] In some other embodiments, the unmanned vehicle **102** can have a controller **212** which includes, but is not restricted, a detection unit **202**, a memory unit **204**, a position unit **206**, a communication unit **208** and, a control unit **210**. The controller **212** is configured to control the movement of the unmanned vehicle **102** along the planned path. In fact, embodiments of the disclosed subject matter are intended to include or otherwise cover any number of components in the controller **212**, including known, related art, and/or later developed technologies to control the movement of unmanned vehicles **102** along the planned paths. In some other embodiments, the base station **108** can include a controller (not shown), used to receive and transmit planned path data to the unmanned vehicles **102**.

[0051] In some embodiments, the detection unit **202** can be configured to detect the obstacle **104** present in operational of path of the unmanned vehicle **102** and a potential collision of the unmanned vehicle **102** with the obstacle **104**. The obstacle **104** can be, but not restricted to, building, antenna, terrain features, and so forth. The detection unit **202** may use one or more sensing devices, which may include, but not restricted to, a camera, a location based sensor, an electromagnetic spectrum sensor, gamma ray sensors, biological sensors, chemical sensors, thermal sensor, and the like. In fact, embodiments of the disclosed subject matter are intended to include or otherwise cover any type of sensing device in the detection unit **202** including known, related art, and/or later developed technologies to detect the obstacle **104** present in the operational path of the unmanned vehicle **102**. Yet, in some other embodiments, the detection unit **202** can be configured to detect and/or determine the structural parameters of the obstacle **104**. The structural parameters of the obstacle **104** can be, but are not restricted to, height, width, length and so forth. The unmanned vehicle **102** can avoid the obstacle **104** based on the detected structural parameters. Further, the unmanned vehicle **102** can communicate the structural parameters of the obstacle **104** with the companion unmanned vehicles **102**, such that the companion unmanned vehicles **102** may also employ evasive maneuvers, if required, to avoid the obstacle **104**.

[0052] In some embodiments, the detection unit **202** can be configured to detect another unmanned vehicle or fleets which are not a part of the network. Such unknown unmanned vehicles can essentially be considered an environmental hazard. Therefore, each of the unmanned vehicle **102** of the system **100** can act accordingly to divert its course while maintaining the same planned path strategies within a given fleet to avoid inter-fleet collision.

[0053] In some other embodiments, the detection unit **202** can be configured to detect potential collision of the unmanned vehicle **102*a*** or an optionally manned vehicle with the companion unmanned vehicles **102*b*** to **102*n*** or optionally manned vehicle. In addition, the detection unit **202** may use digital maps such as, but not restricted to, Digital Terrain Elevation Data (DTED) to impede or avoid unexpected events. The digital maps may be populated using information from satellite and/or using information gathered from online and/or offline sources.

[0054] Further, the memory unit **204** includes data used to impede or avoid collisions among unmanned vehicles **102** or optionally manned vehicles, and to avoid collisions between the unmanned vehicles **102** or optionally manned vehicles and obstacles **104**. In some embodiments, the memory can store relative position of the companion unmanned vehicle **102** and the information provided by the detection unit **202**. In certain embodiment, the memory unit **204** can be configured to store the planned path of the unmanned vehicle **102**.

[0055] In some other embodiments, the memory unit **204** may store information used to generate a planned path for the unmanned vehicle **102** and/or data used to determine whether the unmanned vehicle **102** needs to re-calculate a new planned path. In fact, embodiments of disclosed subject matter are intended to include or otherwise cover any type of data that is required for the operation of the unmanned vehicle **102**.

[0056] In addition, the memory unit **204** may be, but not restricted to, a Random Access Memory (RAM) unit and/or a non-volatile memory unit such as a Read Only Memory (ROM), optical disc drive, magnetic disc drive, flash memory, Electrically Erasable Read Only Memory (EEPROM), and so forth. Moreover, the memory unit **204** may include instructions to enable the controller to control the movement of the unmanned vehicle **102**. In fact, embodiments of the disclosed subject matter are intended to include or otherwise cover any type of memory device including known, related art, and/or later developed technologies to store the information required to perform the above discussed operations.

[0057] In some embodiments, the position unit **206** can be configured to determine position data of the unmanned vehicles **102**. The position data may include, but not restricted to, latitude, longitude, and altitude of the unmanned vehicles **102**. In alternate embodiments, the position data may include any other data that is required to determine the position of the unmanned vehicle **102** and/or obstacle **104** present in the operational path of the unmanned vehicles **102**. The position unit **206** can include, but not restricted to, a satellite navigation unit **206*a*** such as a Global Positioning System (GPS), United States Geological Survey (USGS) terrain data, and an inertial navigation unit **206*b***. In fact, embodiments of the disclosed subject matter are intended or otherwise include any type of navigation devices to determine location of the unmanned vehicles **102** and/or the obstacle **104** present in the operational path of the unmanned vehicles **102**. In various embodiments, the position unit **206** may employ various methods to determine the positions of the companion unmanned vehicles **102** and the obstacle **104** relative itself. Such methods can include, but not restricted to, ranging tones, telemetry data, terrain data, optical imaging, and so forth.

[0058] In some embodiments, the satellite navigation unit **206***a* is configured to receive a satellite signal that is indicative of the current position of the unmanned vehicle **102**. The satellite navigation unit **206***a* may provide autonomous geo-spatial positioning with global coverage. In some embodiments, the satellite navigation unit **206***a* allows the unmanned vehicle **102** to determine its location (longitude, latitude and altitude/elevation). In various embodiments, the satellite navigation unit **206***a* may include a receiver for receiving satellite signals.

[0059] In some other embodiments, the inertial navigation unit **206***b* is configured to determine the current position of the unmanned vehicle **102** relative to a reference or an initial position. The inertial navigation unit **206***b* may enable navigation of the unmanned vehicle **102** based on changes in an inertia of the unmanned vehicle **102**. Moreover, the inertial navigation unit **206***b* can include, but not restricted to, various components such as, accelerometers, gyroscope and so forth.

[0060] The gyroscope can be used to determine an absolute angular reference. The inertial navigation unit **206***b* can include one or more gyroscopes, such as, but not restricted to, a laser gyroscope, a vibrating gyroscope, a hemispherical resonator gyroscope, a fiber optic gyroscope, and the like. The inertial navigation unit **206***b* can also include one or more accelerometers to measure acceleration of the unmanned vehicle **102** about one or more axes defined with respect to the unmanned vehicle **102**.

[0061] The inertial navigation unit **206***b* can have angular and linear accelerometers to determine change in position. Further, angular accelerometers can be configured to determine the rotation of the unmanned vehicle **102** about multiple axes. In some embodiments, the inertial navigation unit **206***b* can include at least one sensor for each of the three axes. The axes may include an X-axis, a Y-axis and a Z-axis. Therefore, the inertial navigation unit **206***b* can measure yaw angle and/or velocity, pitch angle and/or velocity, and roll angle and/or velocity of the unmanned vehicle **102**. Moreover, linear accelerometers can be configured to measure non-gravitational acceleration of the unmanned vehicle **102**.

[0062] In an example, the inertial navigation unit **206***b* may calculate acceleration in the x-direction, followed by acceleration in the y-z direction after a certain duration indicating the unmanned vehicle **102** has executed a turn of a particular radius. The inertial navigation unit **206***b* can record all of these changes in inertia to determine the displacement between the current position and the initial position. Specifically, the inertial navigation unit **206***b* can navigate the unmanned vehicle **102** based on the above disclosed changes in acceleration in different planes.

[0063] In a further example, a laser gyroscope of the inertial navigation unit **206***b* may determine the changes in acceleration. In some embodiments, the changes in acceleration are due to, but not restricted to air current that tend to perturb the aerial vehicle **102** rotationally. Such perturbations can cause changes in a pitch, a roll and a yaw of the unmanned vehicle **102**.

[0064] In some embodiments, the inertial navigation unit **206***b* continuously monitors the location, orientation and velocity (direction and speed of movement) of the unmanned vehicle **102**. In alternative embodiments, the inertial navigation unit **206***b* may periodically monitor the movement of the unmanned vehicle **102**. In yet other embodiments, the inertial navigation unit **206***b* may intermittently monitor various parameters of the unmanned vehicle **102** based on requirements.

[0065] Further, the position unit **206** can combine the data from the satellite navigation unit **206***a* and/or the inertial navigation unit **206***b* with pressure data and information of the companion unmanned vehicles **102** to make accurate predictions about the trajectory of each of the unmanned vehicles **102** of the system **100**. The pressure data can be measure by a device such as, but not restricted to, an altimeter.

[0066] In some embodiments, the position unit **206** may integrate a Kalman filter with the inertial navigation unit **206***b* to minimize drift errors and accurately estimate the current position of the unmanned vehicle **102**. The Kalman filter is a set of mathematical equations that provides an efficient computation method to estimate the state of a process (for example, navigation data), in a way that minimizes a mean of a squared error. The Kalman filter may be implemented by any combination of hardware and software. In fact, embodiments of disclosed subject matter are intended to include or otherwise cover any type method to accurately estimate the current position of the unmanned vehicle **102**.

[0067] In yet some other embodiments, the position unit **206** can use ad-hoc peer-to-peer communication (point-to-point communication), to directly send or receive any information to or from the companion unmanned vehicles **102**, rather than communicating information through an intermediary such as, but not restricted to, a base station, another unmanned vehicle, and the like. The information that can be sent or received via peer-to-peer communication network can be, but not restricted to the planned path data, telemetry data, and the like.

[0068] In some other embodiments, the communication unit **208** can be configured to transmit and/or receive data required to impede collisions among unmanned vehicles **102**, and/or to avoid or impede collisions between the unmanned vehicles **102** and obstacles. In an embodiment, the communication unit **208** can include a transmitter for transmitting signals, and a receiver for receiving signals. In an alternative embodiment, the communication unit **208** can include a transceiver for both transmitting and receiving signals. In some other embodiments, the communication unit **208** can transmit and/or receive the data required to generate planned path through the communication network **106**. The communication unit **208** can use 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 disclosed subject matter are intended to include or otherwise cover any type of techniques, including known, related art, and/or later developed technologies to transmit the information required to control the movement of the unmanned vehicle **102** along the planned path.

[0069] In alternate embodiments, the communication unit **208** can transmit and/or receive planned path information to and/or from the companion unmanned vehicles **102**.

[0070] In an embodiment, the control unit **210** can be disposed in communication with the satellite navigation unit **206***a*, the inertial navigation unit **206***b*, and the memory unit **204**. In an exemplary embodiment, the control unit **210** or the controller **212** combines the planned path data, satellite navigation data from the satellite navigation unit **206***a* and inertial navigation data from the inertial navigation unit **206***b*. The combined data is communicated to each of the unmanned vehicles **102** through the communication network **106**. The communication network **106** can also receive similar combined data from the companion unmanned vehicles **102** of the system **100**. Further, the control unit **210** uses the combined data to estimate the current position of each of the companion unmanned vehicles **102**.

[0071] Further, the control unit **210** or the controller **212** can be configured to control the movement of the unmanned vehicle based on at least the comparison between the current position and a planned position. The planned position may be an expected position of the unmanned vehicle **102** based on the planned path. In an example, the control unit **210** may determine a time elapsed from the start of travel along the planned path, and determine the planned position based on the planned position data and the elapsed time.

[0072] The control unit **210** or the controller **212** can regulate the movement of the unmanned vehicle **102** by controlling various components of the unmanned vehicle **102** such as, but not restricted to, rotors, propellers, and flight control surfaces. In fact, embodiments of the disclosed subject matter are intended to include or otherwise cover any component that can control the movements and/or orientation of the unmanned vehicle **102**.

[0073] In some embodiments, the controller **212** or the control unit **210** can be configured to generate a planned path of the unmanned vehicle **102** by using data received from the base station **108**. The planned path data may include, but not restricted to, a speed profile of the path, an altitude profile of the path and a horizontal profile of the path. In some other embodiments, the controller **212** or the control unit **210** can be configured to control movement of the unmanned vehicle **102**, such that the unmanned vehicle **102** moves along the planned path.

[0074] In some embodiment, the controller **212** or the control unit **210** is configured to receive the current position of the unmanned vehicle **102** from the position unit **206**. In further embodiments, the communication unit **208** receive the current position of the companion unmanned vehicles **102** of the system **100**. In certain embodiments, the controller **212** or the control unit **210** can be configured to estimate a potential collision between the unmanned vehicle **102** and the companion unmanned vehicles **102** based on the current position of each of the unmanned vehicles **102** of the system **100**.

[0075] In some embodiments, the control unit **210** or the controller **212** can be configured to control the movement of the unmanned vehicle **102** in order impede or avoid the potential collision between the unmanned vehicle **102** and the companion unmanned vehicles **102**. In some other embodiments, the control unit **210** or the controller **212** can be configured to control the elevation and velocity of the unmanned vehicle **102** to impede or avoid collisions due to sudden changes in the trajectory of the unmanned vehicle **102**.

[0076] In some embodiments, the controller **212** or the control unit **210** may continually monitor the location of the unmanned vehicle **102** using the satellite navigation unit **206***a*. Further, the controller **212** or the control unit **210** may detect a loss of satellite signal at the satellite navigation unit **206***a*. The loss of satellite signal may occur due to various factors including turbulent weather conditions, solar flares, the presence of a foreign object blocking the signal, hardware or software faults etc. Hardware or software faults may include malfunctioning of the satellite navigation unit **206***a*. In an exemplary embodiment, loss of signal may occur when the unmanned vehicle **102** is at a location that is not receptive to satellite transmissions. Moreover, loss of satellite signal may include drop of a strength of the satellite signal below a predetermined strength. Further, if the satellite signal has been lost, the controller **212** or the control unit **210** is configured to receive the current position of unmanned vehicle **102** from the inertial navigation unit **206***b*.

[0077] In yet another embodiment, the controller **212** or the control unit **210** can be configured to determine the planned position of the unmanned vehicle **102** based on the planned path so as to determine a deviation of the unmanned vehicle **102** from the planned path. In some other embodiments, the controller **212** or the control unit **210** can be configured to compare the current position determined by the inertial navigation unit **206***b* with the planned position based on the planned path during loss of satellite signal.

[0078] In some embodiments, the controller **212** or the control unit **210** can be configured to estimate a potential collision between the unmanned vehicle **102** and the companion unmanned vehicles **102** of the system **100** based on the current position derived from the inertial navigation unit **206***b* of the unmanned vehicle **102**, the planned position of the unmanned vehicle **102** based on the planned path, and current positions of the companion unmanned vehicles **102**.

[0079] In alternate embodiments, the controller **212** or the control unit **210** can be configured to estimate a potential collision between the unmanned vehicle **102** and the companion unmanned vehicles **102** of the system **100** based on the current position derived from the satellite navigation unit **206***a* of the unmanned vehicle **102**, the planned position of the unmanned vehicle **102** based on the planned path, and current positions of the companion unmanned vehicles **102**.

[0080] In some embodiments, the controller **212** or the control unit **210** of the unmanned vehicle **102** performs various operations such as, but are not limited to, movement of the unmanned vehicle **102**, controlling and coordinating operations of various components of the unmanned vehicle **102**, detecting loss of satellite signal and processing information from the base station **108**. However, in some other embodiments, the controller (not shown) of the base station **108** performs one or more of the above operations. Yet in some other embodiments, the controller **212** of any one of the companion unmanned vehicles **102** performs one or more of the above operations. In fact, embodiments of the disclosed subject matter are intendent to include or otherwise cover any controller including known, related art, and/or later developed technologies that is operationally coupled to the unmanned vehicle **102** to perform one or more of the above operations.

[0081] Operation of the Unmanned Vehicle

[0082] FIG. **3** is a flowchart of a procedure **300** for controlling the unmanned vehicle **102** 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 to control the unmanned vehicle **102** along a planned path.

[0083] In accordance with the procedure **300** illustrated in FIG. **3**, at step **302**, the controller **212** controls the movement of the unmanned vehicle **102** along the planned path. The planned path can include various parameters such as, but not restricted to, a speed profile of the path, an altitude profile of the path and a horizontal profile of the path. In some embodiments, the controller **212** regulates various components of the unmanned vehicle **102** such as rotors, propellers, and flight control surfaces that control the movement and/or orientation of the unmanned vehicle **102**. In some other embodiments, the controller **212** present in the unmanned vehicle **102** may control pitch, roll, yaw and various speed control parameters. In an alternate embodiment, the controller may be a part of the base station **108** and transmits control instructions through the communication network **106** to the unmanned vehicle **102**. The planned path of the unmanned vehicle **102** may be generated in order to complete one or more mission objectives efficiently. Moreover, the planned path of the unmanned vehicle **102** is based on various parameters such as, but are not restricted to, preset operating conditions, planned path of companion vehicles, fuel consumption, time of flight, distance, weather and the like. Preset operating conditions include, but not limited to, restricted geographical locations, height limits and like.

[0084] In some embodiments, the controller **212** of the unmanned vehicle **102** generates the planned path for the unmanned vehicle **102**. In alternate embodiments, the base station **108** generates the planned path and transmits the planned path to the unmanned vehicle **102** through the communication network **106**. In addition, the planned path of each of the unmanned vehicle **102** is communicated to the companion unmanned vehicles **102**. In some embodiments, the planned path data is combined with the satellite navigation data for improved accuracy. Therefore, the controller **212** controls the movement of the unmanned vehicle **102** along a planned path based a satellite navigation unit **206***a*.

[0085] At step **304**, the controller **212** determines a loss of satellite signal at the satellite navigation unit **206***a*. As discussed above, the controller **212** controls the movement of the unmanned vehicle **102** along the planned path with the help of the satellite position as detected by the satellite navigation unit **206***a*. However, in some cases, the satellite signal may not be available or may be inaccurate. For example, in case the unmanned vehicle **102** travels through a tunnel, a crowded urban environment, a mountainous region, a forested area, or any other covered region where the satellite reception is poor, the satellite navigation unit **206***a* may not receive any signal, or receive a weak or intermittent signal. Inability of the controller **212** to determine the current position of the unmanned vehicle **102** based on the satellite signal and cross-checking the current position with the planned path may lead to deviation of the unmanned vehicle **102** from its planned path. Such deviation may increase the probability of the collisions among the unmanned vehicles **102** and/or collisions between the unmanned vehicle **102** and the obstacle **104**.

[0086] At step **306**, the controller **212** determines the planned position of the unmanned vehicle **102** based on the planned path. In some embodiments, in case the satellite signal is lost at the satellite navigation unit **206***a*, the controller **212** may determine the planned position of the unmanned vehicle **102** based on planned path data stored in the memory unit **204**. In some embodiments, the planned path can include a series of positions, speeds, altitudes, orientation and the like. Further each position may be linked to a corresponding speed, altitude and orientation. Therefore, the controller **212** can determine planned position of the unmanned vehicle **102** based on above disclosed parameters.

[0087] At step **308**, a current position of the unmanned vehicle **102** is determined by the inertial navigation unit **206***b*. In some embodiments, the change in vehicle's inertia is determined to estimate the current position of the unmanned vehicle **102**. The inertial navigation data contains the current position of the unmanned vehicle relative to an initial position. In some embodiments, the initial position may be the position of the unmanned vehicle **102** at which the satellite signal is lost. The initial position may be stored in the memory unit **204**. In some other embodiments, the controller **212** determines a current trajectory of the unmanned vehicle **102** based on the current position determined by the inertial navigation unit **206***b*. The current trajectory may be calculated based on a current position, a current heading, and current speed of the unmanned vehicle **102**. Further, the current trajectory may also include future positions of the unmanned vehicle **102**.

[0088] Further, at step **310**, the controller **212** compares the current position with the planned position. The controller **212** determines a difference between the planned position based on planned path and the current position determined by the inertial navigation unit **206***b*. In some embodiment, the controller **212** may compare one or more parameters of the current position with equivalent parameters of the planned position. For example, the controller **212** may compare the current horizontal location, the current altitude and the current heading with the planned horizontal location, the planned altitude and the planned heading, respectively, of the unmanned vehicle **102**. After computing the differences between the individual parameters, the controller **212** may ignore differences that are less than corresponding tolerance values. The tolerance values may be based on allowable instrument errors and are of magnitudes that are too low to interfere with the navigation of the unmanned vehicle **102**.

[0089] Next, at step **310**, the controller **212** controls the movement of the unmanned vehicle **102** based on the comparison between the current position and the planned position of the unmanned vehicle **102**. The controller **212** may be further configured to at least reduce a difference between the current trajectory of the unmanned vehicle **102** and the planned path. In some other embodiments, if the unmanned vehicle **102** is massively off course and/or it is difficult to reduce the difference between the current trajectory of the unmanned vehicle **102** and the planned path, the controller **212** may calculate a new planned path distinct from the original planned path.

[0090] Further, the current position of each of the companion unmanned vehicles **102***b* to **102***n* may be transmitted to the unmanned vehicle **102***a*. In some embodiments, the controller **212**, at the unmanned vehicle **102***a*, determines one or more potential collisions between the unmanned vehicle **102***a* and the companion unmanned vehicles **102***b* to **102***n*. Subsequently, the controller **212** of the unmanned vehicle **102***a* controls the movement of the unmanned vehicle **102** to impede or avoid the potential collisions.

[0091] FIG. **4** is a flowchart of a procedure **400** for controlling the unmanned vehicle **102** in accordance with the disclosed subject matter. This flowchart is merely provided for exemplary purposes, and embodiments are intended to include or otherwise cover any methods or procedures to control the unmanned vehicle **102** along a planned path.

[0092] In accordance with the flowchart of FIG. **4**, at step **402**, the controller **212** moves the unmanned vehicle **102** along a planned path with the help of satellite navigation and stored planned path data. In some embodiments, the planned path is based on one or more parameters such as, but not restricted to, a starting position, a destination, mission requirements, no fly zones, fuel availability and so forth. In some embodiments, the controller **212** may generate the planned path for the unmanned vehicle **102**. In some other embodiments, the controller of the base station **108** may generate the planned path for the unmanned vehicle **102** and transmit it to the unmanned vehicle **102** and/or the companion unmanned vehicles **102**. In addition, controller **212** may combine the planned path of the unmanned vehicle **102** with satellite navigation for accurate navigation.

[0093] At step **404**, the controller **212** detects a loss of satellite signal at the satellite navigation unit **206***a*. In case the controller **212** detects a loss of the satellite signal, the procedure **400** executes step **406** to **412**. In case the controller **212** detects that the satellite navigation unit **206***a* is receiving satellite signal, then the procedure **400** proceeds to step **414**.

[0094] In case of loss of satellite signal, the controller **212**, at step **406**, determines the planned position of the unmanned vehicle **102** based on the planned path. The controller **212** may also store the position at which the satellite signal is lost in the memory unit **204**. As discussed, the planned path data may include, but not restricted to, a series of positions, speeds, altitudes, orientation and the like. In addition, each position in a planned path may be linked to a corresponding speed, altitude and orientation. So, in case of loss of satellite signal, the controller **212** can determine the planned position of the unmanned vehicle **102** based on the planned path data. In some embodiments, the memory unit **204** may store the planned path data of the unmanned vehicle **102** and the companion unmanned vehicles **102**. In alternate embodiments, the base station **108** stores the planned path data of the unmanned vehicle **102** and the companion unmanned vehicles **102**, and transmits the planned path data to the unmanned vehicle **102** through the communication network **106**.

[0095] Further, at the step **408**, the controller **212** determines the current position of the unmanned vehicle **102** by the inertial navigation unit **206***b*. The inertial navigation unit **206***b* is configured to determine the current position of the unmanned vehicle **102** based on changes to the inertia of the unmanned vehicle **102**. Further, the inertial navigation unit **206***b* can use various instruments such as, but not restricted to, a laser gyroscope, a vibrating gyroscope, a hemispherical resonator gyroscope, a fiber optic gyroscope and one or more accelerometers to measure the change in inertia. Therefore, the inertial navigation unit **206***b* facilitates independent navigation of the unmanned vehicle **102** in case of loss of satellite signal.

[0096] At step **410**, the controller **212** calculates the difference between the current position of the unmanned vehicle **102** and the planned position of the unmanned vehicle **102** based on planned path. Further the controller **212** can be configured to compare the difference between the current position and the planned position with a threshold value. In some embodiments, the threshold value is based on various parameters such as, but not restricted to, position, distance and the like. Further, the controller **212** determines whether it has to modify the planned path or generate a new planned path in order to impede or avoid collisions, as well as achieve the target based on the comparison between the threshold value and the calculated difference.

[0097] At step **412**, the controller **212** controls the movement of the unmanned vehicle **102** based on the comparison between the threshold value and the calculated difference between the current position and the planned position. After step **412**, the procedure **300** may return to step **404** wherein the controller **212** may again check whether the satellite navigation unit **206***a* is receiving satellite signal.

[0098] In case the satellite navigation unit **206***a* is receiving satellite signal, the controller **212**, at step **414**, controls the unmanned vehicle **102** based on the planned path data and the current position derived from the satellite navigation unit **206***a*.

[0099] Next, at step **416**, the controller **212** checks of the target or the mission objective is achieved. If the target is not achieved, the procedure **400** returns to step **402** and repeats all steps from **402** to **416**. However, in case the target is achieved, the procedure **400** ends.

IV. Exemplary Embodiments

[0100] An exemplary operation of the system **500** will be now described with reference to FIGS. **5**A and **5**B. The unmanned vehicles **102** can be deployed from the base station **108** or any other suitable location. In some embodiments, the unmanned vehicles **102** can also be independently deployed from multiple locations. After deployment, the unmanned vehicles **102** may communicate with each other and autonomously form the system **500**. In another embodiment, the base station **108** may transmit information to each of the unmanned vehicles **102** required to form the system **500**. After the system **500** is formed, a central platform or a leader vehicle can be dynamically selected among the unmanned vehicles **102**. In the illustrated embodiment, the unmanned vehicle **102***a* acts as the central platform that communicates with the base station **108** on behalf of the companion unmanned vehicles **102***b* to **102***n*, and controls the collective behavior of system **500** of unmanned vehicles **102**. However, in alternative embodiments, each of the unmanned vehicles **102** can autonomously control its operations and cooperate with other unmanned vehicles **102** without any central platform.

[0101] In some embodiments, the unmanned vehicles **102** may form an autonomous vehicle swarm upon deployment. Further, the unmanned vehicles **102** may autonomously arrange themselves into different types of formations for various purposes, including collision avoidance, energy conservation, safeguarding assets, ease of communication, tracking and analyses of objects, etc.

[0102] In an embodiment, the unmanned vehicles **102** can arrange themselves in an energy efficient formation in order to conserve energy during flight. In an exemplary scenario, an energy efficient formation is a V-formation in which the unmanned vehicles **102** form a substantially V-shaped arrangement. The unmanned vehicle **102***a* acting as the central platform may form the apex of the V-shape. The V-formation may reduce an induced drag on the unmanned vehicles **102**, thereby reducing energy consumption. A distance and/or angle between the unmanned vehicles may be dynamically changed based on ambient conditions to minimize energy consumption. Further, the unmanned vehicles **102** may periodically switch positions within the V-shape based on a remaining energy of each of the unmanned vehicles **102**.

[0103] In another embodiment, the unmanned vehicles **102** can arrange themselves in a defensive formation to safeguard one or more assets. The assets can be an aircraft, a terrestrial vehicle, a ship, a stationary object (e.g., a communication tower or a building) etc.

[0104] FIG. **5**A illustrates an exemplary scenario illustrating the system **500**, wherein the unmanned vehicles **102***a* to **102***n* travels along respective planned paths **502***a* to **502***n* in synchronization with satellite navigation. The system **500** illustrates the planned paths **502***a* to **502***n* of the unmanned vehicles **102**, hereinafter collectively referred to as a planned path **502**. The controller **212** of each of the unmanned vehicles **102** combines satellite navigation data with planned path data to accurately navigate the unmanned vehicles **102** along their planned path **502**. In an example, the controller **212** may compare the current position derived from the satellite navigation unit **206***a* with the planned path data in order to navigate the corresponding unmanned vehicle **102** along its planned path **502**.

[0105] The controller **212** can determine the planned position of the unmanned vehicle **102** based on the planned path **502** stored in the memory unit **204**. Further, the controller controls the movement of the unmanned vehicle **102** such that the unmanned vehicle **102** travels along the planned path **502**, while avoiding or impeding collisions among the unmanned vehicles **102** and/or between the unmanned vehicles **102** and any obstacle. As shown, the planned paths **502** of the unmanned vehicles **102** are from a source to a destination.

[0106] FIG. **5**B illustrates an exemplary scenario illustrating loss of satellite signal at the unmanned vehicle **102***a*. In FIG. **5**B, the unmanned aerial vehicles **102** travels along the planned paths **502**. The controller **212** of the unmanned aerial vehicles **102***a* detects a loss of satellite signal. The controller **212** of the unmanned vehicle **102***a* determines the current position of the unmanned vehicle **102***a* based on the position data provided by the inertial navigation unit **206***b*. The inertial navigation unit **206***b* is configured to determine the current position of the unmanned vehicle **102** relative to an initial position P**1**'. The initial position 'P**1**' may be the position at which satellite signal is lost. Further, the initial position P**1**' may be stored within the memory unit **204**. Further, the controller **212** of the unmanned vehicle **102** determines the difference between the planned position and current position derived from the inertial navigation unit **206***b*. The controller **212** is configured to compare the measured difference with a threshold value which is based on, but not restricted to, speed, distance, velocity, time and like. Further, based on the comparison between the threshold value and the measured difference, the unmanned vehicle **102** determines if it has to modify the planned path or generate a new planned path in order to impede or avoid collisions, and achieve the target.

[0107] As illustrated in FIG. **5**B, the unmanned vehicle **102***a* may deviate from the planned path **502***a* due to loss of satellite signal at the initial position 'P**1**'. The loss of satellite signal may be due to an object **506** that hinders reception of satellite signal at the satellite navigation unit **206***a* of the unmanned vehicle **102***a*. The object **506** may be a tree, a mountain, a building, and the like. Alternatively, loss of satellite signal may be due to any hardware and/or software faults, for example, malfunctioning of the receiver of the satellite navigation unit **206***a*.

[0108] The unmanned vehicle **102***a* travels along a path **504***a* after loss of satellite signal. The controller **212** navigates the unmanned vehicle **102***a* along the path **504***a* based on planned path data and positional data obtained from the inertial navigation unit **206***b*. However, due to errors (e.g., drift errors) inherent in inertial navigation, the path **504***a* may deviate from the planned path **502***a* of the unmanned vehicle **102***a*.

[0109] During travel along the path **504***a*, the controller **212** of the unmanned vehicle **102***a* may also receive current positions from each of the companion unmanned vehicles **102***b* to **102***n*, and correct a trajectory of the unmanned vehicle **102***a* to at least reduce a deviation between the path **504***a* and the planned path **502***a*. Further, the controller **212** may also communicate the current position of the unmanned vehicle **102***a* to the companion unmanned vehicles **102***b* to **102***n* so that they can act accordingly in order to avoid or impede collisions.

[0110] After travelling on the path **504***a* for a duration, the controller **212** may detect satellite signal received at the satellite navigation unit **206***a*. This may be due an increased separation between the unmanned vehicle **102***a* and the object **506**. Upon receiving satellite position data from the satellite navigation unit **206***a*, the controller **212** may modify the path of the unmanned vehicle **102***a* such that the unmanned vehicle **102***a* may move towards the planned path **502***a*. However, in alternative scenarios, the controller **212** may re-calculate a new planned path (not shown) for the unmanned vehicle **102***a* based on the deviation of the unmanned vehicle **102***a* from the planned path **502***a*.

[0111] As illustrated in FIG. **5**B, the controller **212** may generate a path **508***a* in order to move the unmanned vehicle **102***a* to the planned path **502***a* at a position 'P**2**'. The path **508***a* may be generated based on various factors, such as current positions of each of the unmanned vehicles **102***a* to **102***n*, presence of any obstacles etc. Further, the controller **212** may also communicate the path **508***a* to the companion unmanned vehicles **102***b* to **102***n* so that they may modify their paths accordingly to impede or avoid any collisions.

[0112] Various operations of the system **500** including the unmanned vehicle **102***a* to **102***n*, as described above, are for illustration purposes only, and the various embodiments are intended to include or otherwise cover any operation of unmanned vehicles based on inertial navigation and satellite navigation that may be beneficial.

V. Other Exemplary Embodiments

[0113] FIG. **6** illustrates a computer system **600** upon which an embodiment of the invention may be implemented. The computer system **600** may be part of the controller **212**, the control unit **210** and/or the controller of the base station **108**. In fact, the computer system **600** can be part of any component of the unmanned vehicle **102**. 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 system **600**. The computer system **600** is programmed (e.g., via computer program code or instructions) to control the unmanned vehicles **102** 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 controlling the unmanned vehicle **102**.

[0114] 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**.

[0115] The processor (or multiple processors) **604** performs a set of operations on information as specified by computer program code related to control the unmanned vehicle **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 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.

[0116] 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.

[0117] Information, including instructions for controlling the unmanned vehicle **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.

[0118] 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.

[0119] 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** controlling the unmanned vehicle **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.

[0120] 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.

[0121] 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**.

[0122] 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).

[0123] 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**.

[0124] 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.

[0125] 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

[0126] 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.

[0127] 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 or an optionally manned vehicle, including, an unmanned or optionally manned aerial vehicle, an unmanned or optionally manned terrestrial vehicle (for example, a car), an unmanned or optionally manned aquatic vehicle, an unmanned or optionally manned railed vehicles, an unmanned or optionally manned spacecraft, a drone, a gyrocopter etc. In fact, embodiments are intended to include or otherwise cover any configuration of an unmanned vehicle or an optionally manned vehicle.

[0128] 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.

[0129] Embodiments are disclosed above in the context of controlling an unmanned vehicle or an optionally manned vehicle in order to impede or avoid collisions between the unmanned vehicle or the optionally manned vehicle, and a companion vehicle.

[0130] Embodiments are disclosed above in the context of controlling an unmanned vehicle or an optionally manned vehicle in order to impede or avoid collisions between the unmanned vehicle or the optionally manned vehicle, and an obstacle. Embodiments are intended to cover any obstacle, such as, but not restricted to, trees, hills, mountains, buildings, towers, corals, waterbodies, sand banks, orbital debris and so forth. Embodiments are also intended to cover any movable obstacle, such as, but not restricted to, birds, aircraft, watercraft, spacecraft, terrestrial vehicles, and so forth.

[0131] Embodiments are disclosed above in the context of fleet of unmanned aerial vehicle. However, embodiments are intended to cover any unmanned vehicle such as unmanned aquatic vehicle, unmanned terrestrial vehicle, and so forth.

[0132] Embodiments are intended to cover fleets of unmanned vehicles, fleets of optionally manned vehicles, or fleets having both unmanned vehicles and optionally manned vehicles.

[0133] Embodiments are disclosed above in the context of an onboard controller. However, embodiments are intended to cover any controller that is operationally coupled to an unmanned vehicle.

[0134] Embodiments are disclosed above in the context of single controller to control the movement of an unmanned vehicle. However, embodiments are intended to include or otherwise cover any number of controllers required to control the movement of the unmanned vehicle along a planned path.

[0135] Embodiments are disclosed above in the context of an inertial navigation system to navigate the unmanned vehicle. However, embodiments are intended to include or otherwise cover any navigation system, method or technique to navigate the unmanned vehicle.

[0136] Embodiments are disclosed above in the context of usage of an inertial navigation system to navigate an unmanned vehicle in case of loss of satellite signal. However, embodiments are intended to include or otherwise cover any inertial navigation system, method or technique to navigate the unmanned vehicle based on a change in its inertia.

[0137] Embodiments are disclosed above in the context of usage of an inertial navigation system and current position data of companion unmanned vehicles to navigate an unmanned vehicle. However, embodiments are intended to include or otherwise cover combining any position data with inertial navigation to navigate the unmanned vehicle.

[0138] Embodiments are disclosed above in the context of usage of an inertial navigation system to navigate an unmanned vehicle in order to impede or avoid collisions with companion unmanned vehicles and/or obstacles. However, embodiments are intended to include or otherwise cover achieving any mission objective by using inertial navigation.

[0139] Embodiments are disclosed above in the context of usage of an inertial navigation system to navigate an unmanned vehicle along a planned path. However, embodiments are intended to include or otherwise cover navigating the unmanned vehicle along a dynamically generated path by using inertial navigation.

[0140] Embodiments are intended to include or otherwise cover any method or technique to navigate the unmanned vehicle based on satellite navigation, inertial navigation, or a combination thereof.

[0141] Embodiments are also intended to include or otherwise use satellite navigation to accurately navigate the unmanned vehicle along a planned path.

[0142] Embodiments are also intended to include or otherwise use any type of sensing device to detect an obstacle present in the operational path of the unmanned vehicle.

[0143] Exemplary embodiments are intended to include and/or otherwise cover any mode of communication among the unmanned vehicles and the unmanned vehicle and the base station.

[0144] Exemplary embodiments are also intended to include and/or otherwise cover a defensive formation of the unmanned vehicle swarm to safeguard one or more assets. The assets can be an aircraft, a terrestrial vehicle, a ship, a stationary object (e.g., a communication tower or a building) etc.

[0145] Exemplary embodiments are also intended to include and/or otherwise a V-formation of the unmanned vehicle 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 receive and mutually combine images of the objects. However, embodiments of the disclosed subject matter are intended to include or otherwise cover any type of formation that may be beneficial.

[0146] Embodiments are also intended to include or otherwise cover methods of manufacturing the unmanned 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.

[0147] 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 airbag housing assemblies disclosed above.

[0148] 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 having a satellite navigation unit and an inertial navigation unit, the unmanned vehicle operatively coupled to a controller, the method comprising:

controlling, by the controller, a movement of the unmanned vehicle such that the unmanned vehicle moves along a planned path;

detecting, by the controller, a loss of a satellite signal at the satellite navigation unit;

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

determining, by the inertial navigation unit, a current position of the unmanned vehicle;

comparing, by the controller, the current position determined by the inertial navigation unit with the planned position based on the planned path; and

controlling, by the controller, a movement of the unmanned vehicle based on at least the comparison between the current position and the planned position.

2. The method of claim **1**, wherein the planned path comprises a speed profile of the path, an altitude profile of the path and a horizontal profile of the path.

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

determining, by the controller, a difference between the planned position based on the planned path and the current position determined by the inertial navigation unit;

determining, by the controller, a current trajectory of the unmanned vehicle based on the current position; and

controlling, by the controller, the movement of the unmanned vehicle to at least reduce a difference between the trajectory of the unmanned vehicle and the planned path.

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

receiving, by the satellite navigation unit, a satellite signal indicative of the current positon of the unmanned vehicle; and

controlling the movement of the unmanned vehicle based on at least the planned path and the satellite signal received by the satellite navigation unit.

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

receiving, at the unmanned vehicle, a current position of a companion unmanned vehicle;

estimating, by the controller, a potential collision between the unmanned vehicle and the companion unmanned vehicle based on the current position of each of the unmanned vehicle and the companion unmanned vehicle; and

controlling, by the controller, the movement of the unmanned vehicle to impede the potential collision between the unmanned vehicle and the companion unmanned vehicle.

6. An unmanned vehicle, comprising:

a satellite navigation unit configured for receiving a satellite signal indicative of a current position of the unmanned vehicle;

an inertial navigation unit configured for determining the current position of the unmanned vehicle relative to an initial position;

a memory unit configured for storing a planned path of the unmanned vehicle;

a control unit disposed in communication with the satellite navigation unit, the inertial navigation unit and the memory unit, the control unit including a position unit and configured to:

detect a loss of satellite signal at the satellite navigation unit,

receive the current position of the unmanned vehicle from the inertial navigation unit,

determine a planned position of the unmanned vehicle based on the planned path,

compare the current position determined by the inertial navigation unit with the planned position based on the planned path, and

control the movement of the unmanned vehicle based on at least the comparison between the current position and the planned position;

a communication unit configured for receiving a second current position of a companion unmanned vehicle sent by the companion unmanned vehicle through at least one of satellite link and a base control station, wherein:

the control unit is further configured to control the movement of the unmanned vehicle further based on the second current position of the companion unmanned vehicle, the control unit is further configured to estimate a potential collision between the unmanned vehicle and the companion unmanned vehicle based on the current position of the unmanned vehicle and the second current position of the companion unmanned vehicle, the control unit is configured to control the movement of the unmanned vehicle to impede the potential collision between the unmanned vehicle and the companion unmanned vehicle, and

the unmanned vehicle is configured to transmit its said current position and the planned path to the companion unmanned vehicle so that the companion unmanned vehicle is configured through a second control unit to determine a need to modify its own second path as well.

7. The unmanned vehicle of claim **6**, wherein the inertial navigation unit comprises at least one of a ring laser gyroscope, a vibrating gyroscope, a hemispherical resonator gyroscope, a fiber optic gyroscope and an accelerometer.

8. The unmanned vehicle of claim **6**, wherein the satellite navigation unit is a Global Position System (GPS) unit.

9. The unmanned vehicle of claim **6**, further comprising a detection unit that is configured to detect an obstacle in a path of the unmanned vehicle, wherein the detection unit includes at least one of a sensor and an imaging unit.

10. The unmanned vehicle of claim **6**, wherein the planned path includes a speed profile of the path, an altitude profile of the path and a horizontal profile of the path.

11. (canceled)

12. (canceled)

13. The unmanned vehicle of claim **6**, wherein the control unit is further configured to:

determine a difference between the planned position based on the planned path and the current position determined by the inertial navigation unit;

determine a current trajectory of the unmanned vehicle based on the current position; and

control the movement of the unmanned vehicle to at least reduce a difference between the trajectory of the unmanned vehicle and the planned path.

14. The unmanned vehicle of claim **6**, wherein the control unit is further configured to:

detect a satellite signal received by the satellite navigation unit; and

control the movement of the unmanned vehicle based on at least the planned path and the satellite signal received by the satellite navigation unit.

15. A system comprising a plurality of unmanned vehicles, each of the plurality of unmanned vehicles including:

a satellite navigation unit that is configured to receive a satellite signal indicative of a current position of the unmanned vehicle;

an inertial navigation unit that is configured to determine the current position of the unmanned vehicle relative to an initial position;

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

a communication unit disposed in communication with other unmanned vehicles, the communication unit configured to receive a current position of each of the other unmanned vehicles; and

a control unit disposed in communication with the satellite navigation unit, the inertial navigation unit, the memory unit and the communication unit, the control unit configured to:

detect a loss of satellite signal at the satellite navigation unit;

receive the current position of the unmanned vehicle from the inertial navigation unit;

determine a planned position of the unmanned vehicle based on the planned path;

receive the current position of each of the other unmanned vehicles from the communication unit; and

control the movement of the unmanned vehicle based on at least the current position determined by the inertial navigation unit, the planned position based on the planned path, and the current position of each of the other unmanned vehicles.

16. The system of claim **15**, further comprising a base station disposed in communication with the plurality of unmanned vehicles, the base station configured to generate the planned path for each of the plurality of unmanned vehicles and transmit the planned paths to corresponding unmanned vehicles.

17. The system of claim **15**, wherein the inertial navigation unit comprises at least one of a ring laser gyroscope, a vibrating gyroscope, a hemispherical resonator gyroscope, a fiber optic gyroscope and an accelerometer.

18. The system of claim **15**, wherein the satellite navigation unit is a Global Position System (GPS) unit.

19. The system of claim **15**, further comprising a detection unit that is configured to detect an obstacle in a path of the unmanned vehicle.

20. The system of claim **15**, wherein the control unit is further configured to:

estimate one or more potential collisions between the unmanned vehicle and the other unmanned vehicles based on the current position of each of the plurality of unmanned vehicles; and

control the movement of the unmanned vehicle to impede the one or more potential collisions between the unmanned vehicle and the other unmanned vehicles.

21. The unmanned vehicle of claim **6**, wherein the control unit is configured to control, remotely, movements of the companion unmanned vehicle based on its position relative to the unmanned vehicle, itself.

22. The unmanned vehicle of claim **6**, wherein the control unit is configured to control the movement of both the unmanned vehicle itself and the companion unmanned vehicle based on a real-time dynamic path.

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