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(54) **VEHICLE, SYSTEM AND METHODS FOR DETERMINING AUTOPILOT PARAMETERS IN A VEHICLE**

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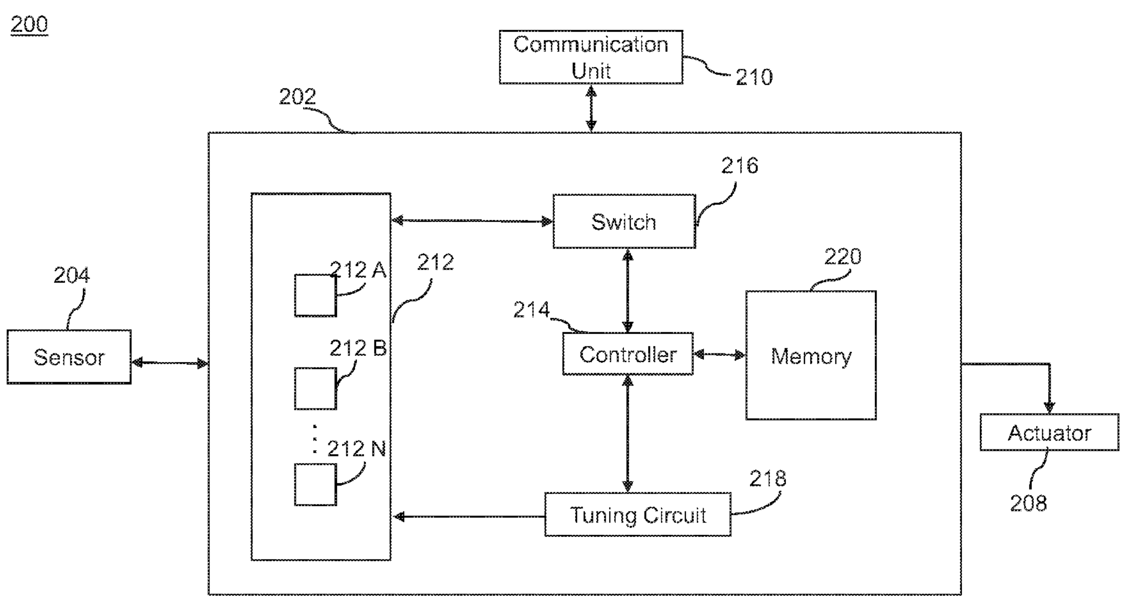
(57) **ABSTRACT**

Some embodiments are directed to a system for use with a vehicle, the system including control circuits for controlling an operation of the vehicle, each of the control circuits implementing autopilot coefficients. The system further includes a sensor that is configured to detect control circuits operating in an untuned or incorrectly tuned state from the control circuits; an electronic switch that is configured to isolate the control circuits in the untuned or incorrectly tuned state from other control circuits; a tuning circuit that is configured to determine tuned values of the autopilot coefficients corresponding to the control circuits in the untuned or incorrectly tuned state; the tuned values of the autopilot coefficients enabling the control circuits to operate in a tuned state; and a memory to store the tuned values of the autopilot coefficients, wherein the electronic switch is further configured to connect the control circuits in the tuned state to the other control circuits.



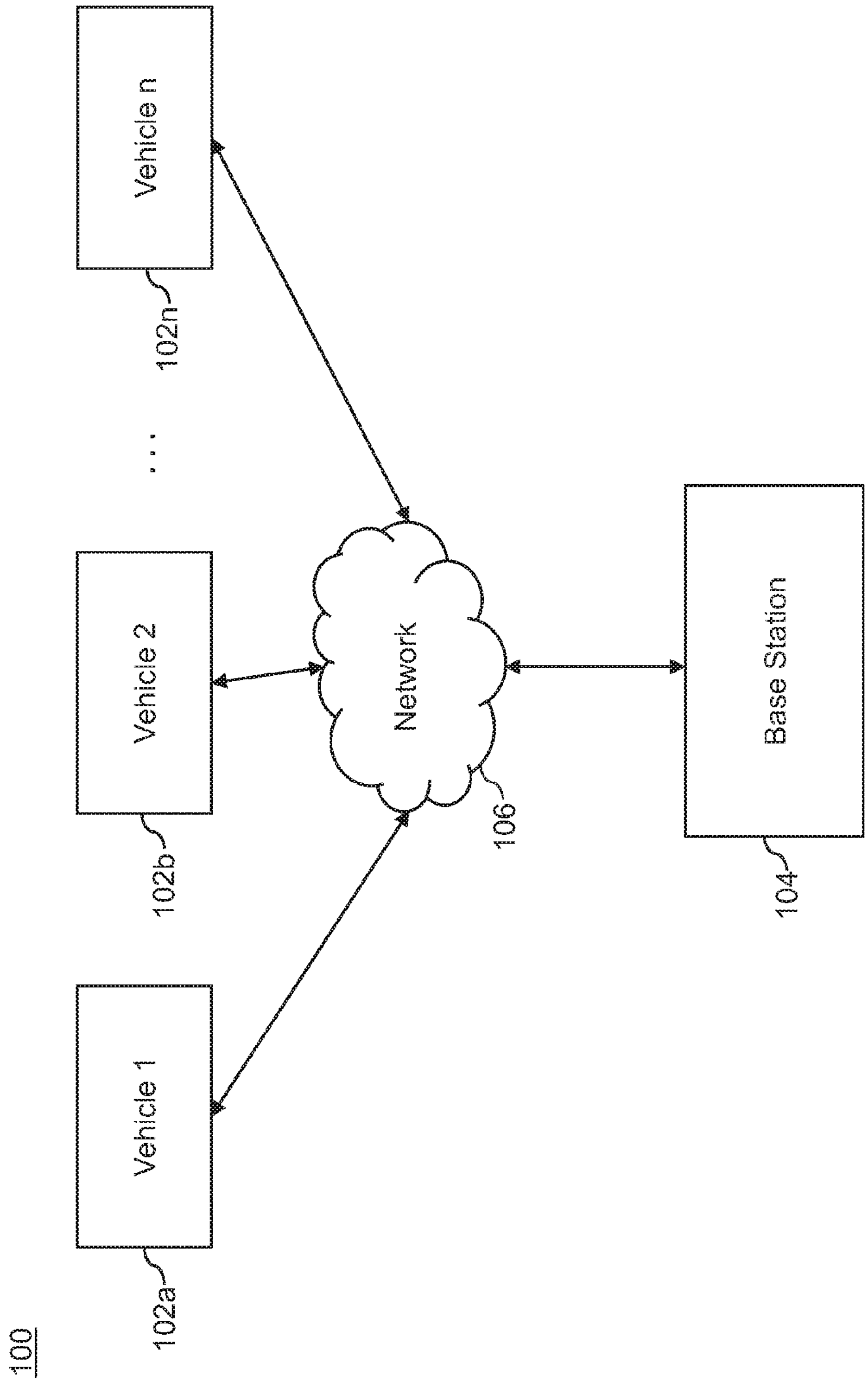

100
Vehicle 1
102a
Vehicle 2
102b
. . .
Vehicle n
102n
Network
106
Base Station
104

FIG. 1

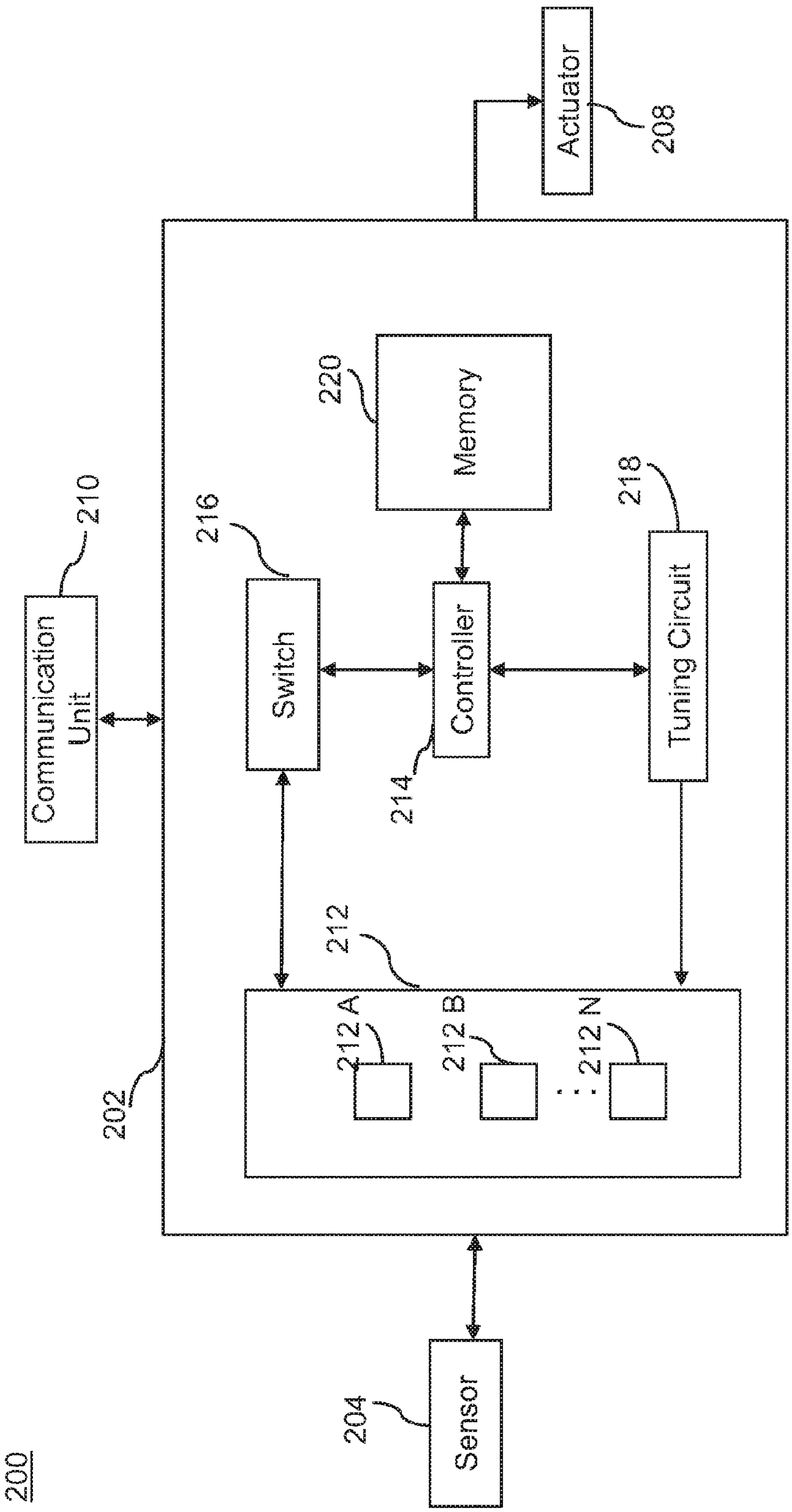

200
Sensor
204
202
212
212 A
212 B
212 N
Switch
216
Controller
214
Memory
220
Tuning Circuit
218
Communication Unit
210
Actuator
208

FIG. 2

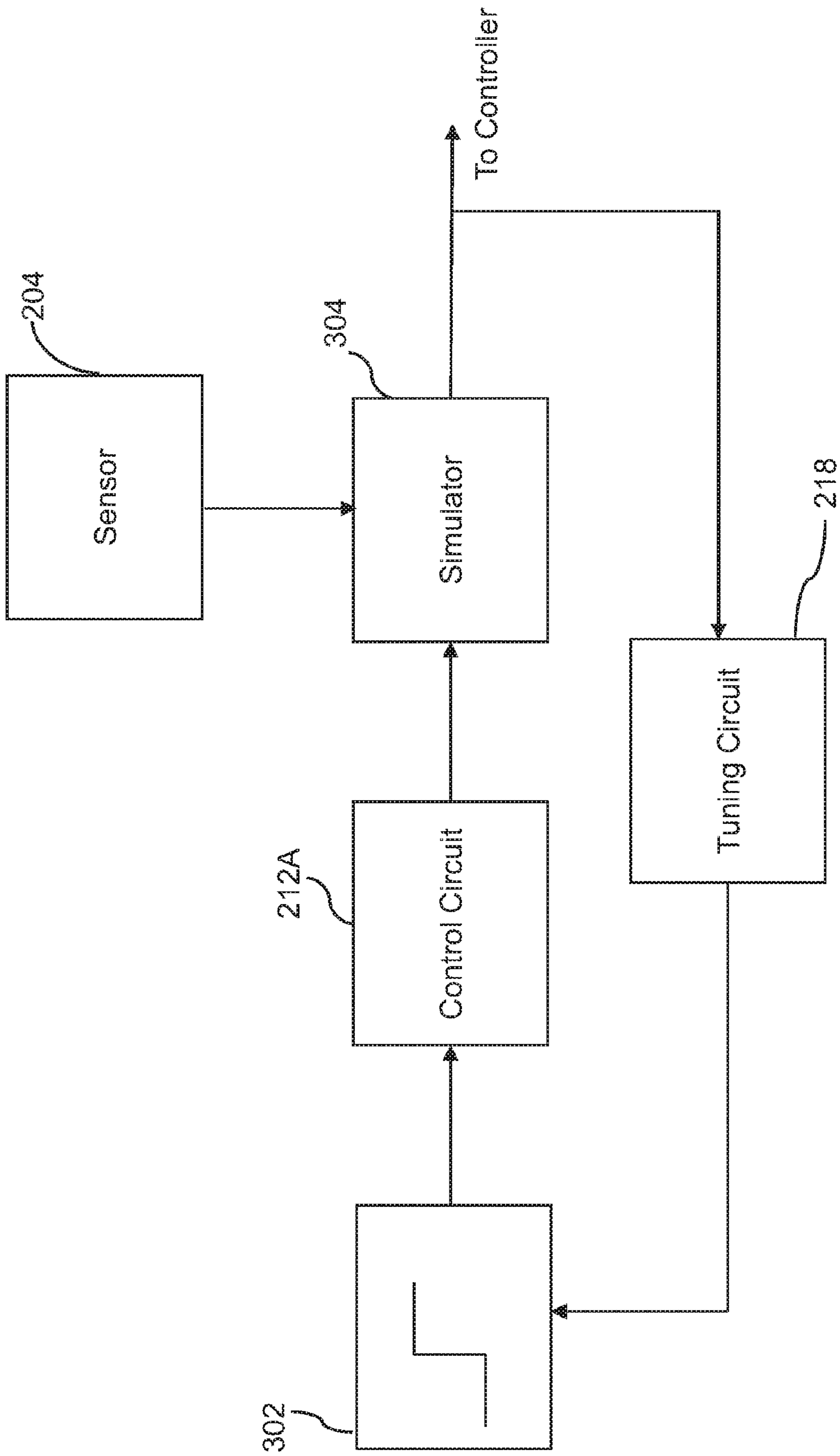

To Controller
204
Sensor
304
Simulator
218
Tuning Circuit
212A
Control Circuit
302

FIG. 3

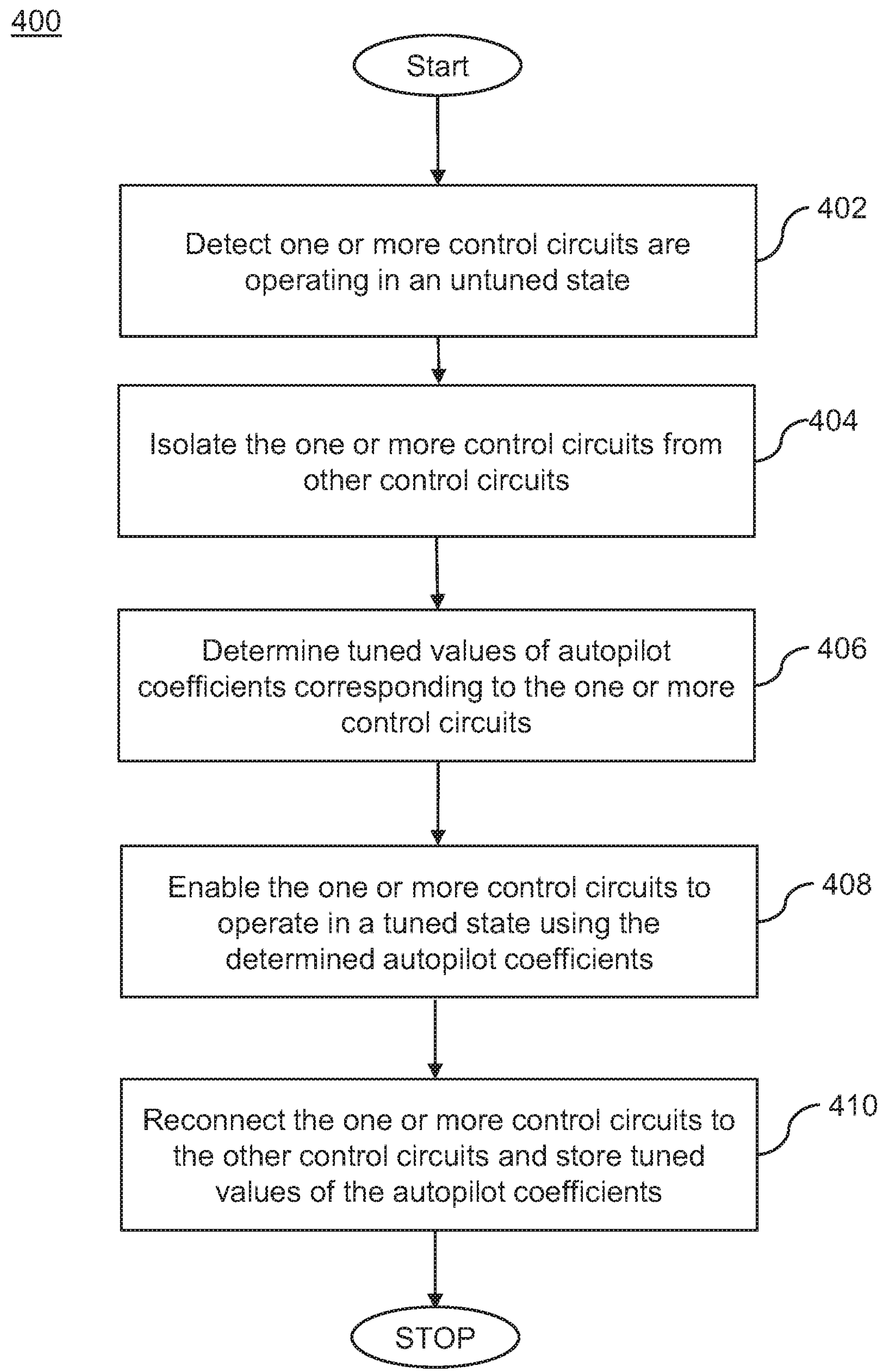

400
Start
Detect one or more control circuits are operating in an untuned state
402
Isolate the one or more control circuits from other control circuits
404
Determine tuned values of autopilot coefficients corresponding to the one or more control circuits
406
Enable the one or more control circuits to operate in a tuned state using the determined autopilot coefficients
408
Reconnect the one or more control circuits to the other control circuits and store tuned values of the autopilot coefficients
410
STOP

FIG. 4

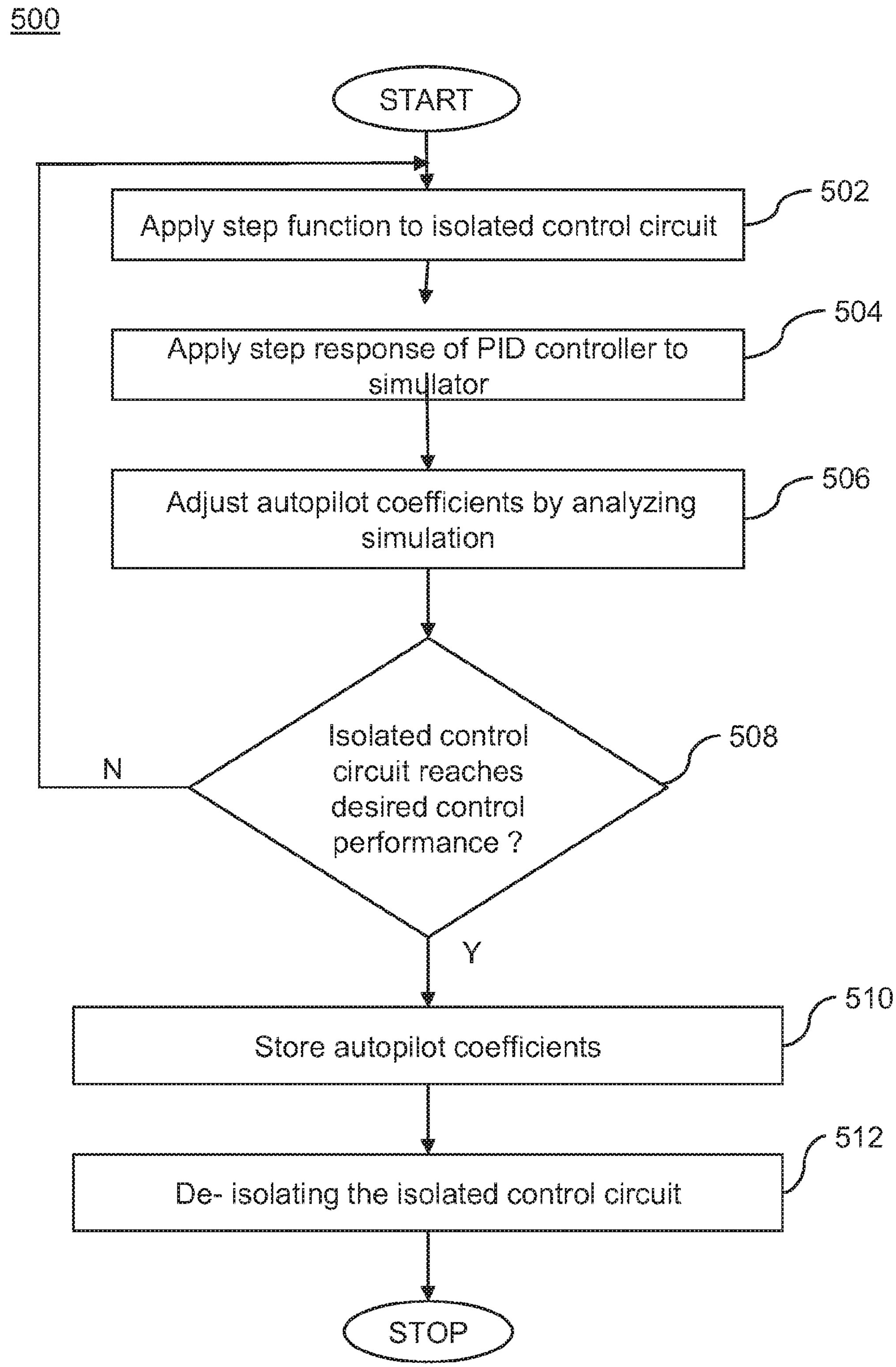

500
START
Apply step function to isolated control circuit
502
Apply step response of PID controller to simulator
504
Adjust autopilot coefficients by analyzing simulation
506
Isolated control circuit reaches desired control performance ?
508
N
Y
Store autopilot coefficients
510
De- isolating the isolated control circuit
512
STOP

FIG. 5

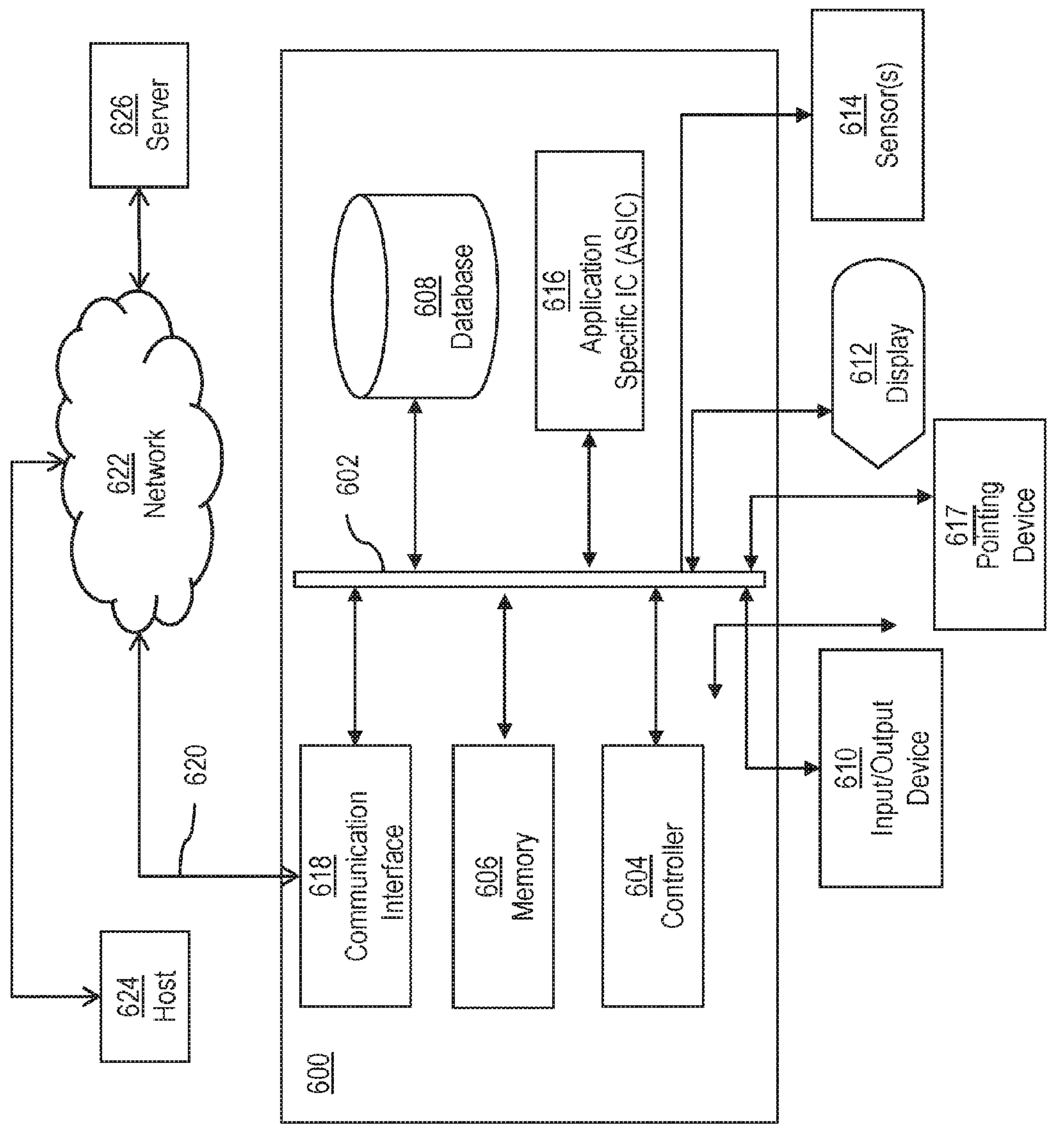

626
Server
622
Network
624
Host
620
618
Communication Interface
606
Memory
604
Controller
600
602
608
Database
616
Application Specific IC (ASIC)
614
Sensor(s)
612
Display
617
Pointing Device
610
Input/Output Device

FIG. 6

VEHICLE, SYSTEM AND METHODS FOR DETERMINING AUTOPILOT PARAMETERS IN A 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 vehicles, systems and methods for autopilot operation of vehicles. In particular, the disclosed subject matter relates to vehicles, systems and methods for determining autopilot parameters for vehicles. These vehicles may be unmanned vehicles, optionally manned vehicles, aerial vehicles, terrestrial vehicles such as cars or all-terrain vehicles, aquatic or oceanic vehicles such as boats or submarines, or space vehicles.

[0003] In any or all of these vehicles, it is often customary to employ an autopilot feature to assume control of the vehicle. Such a control may be used in conjunction with an operator or pilot, or can even be used in fully autonomous or unmanned vehicles.

[0004] Control systems facilitating autopilot features are generally negative feedback-based, in that the autopilot system senses an undesired change in an aspect of the vehicle's motion, and applies a negative feedback signal to a vehicle controller to counteract the undesired (positive) change. For example, an aircraft facing an unexpected ascension due to an air current is controlled by steering the vehicle slightly downwards to maintain a constant altitude.

SUMMARY

[0005] Some related arts use one or more Proportional Integral Differential (PID) control loops to control one or more aspects of a vehicle's operation. In this schema, three PID terms (P, I, and D) are summed to arrive at an overall calculated response u(t) for the system in which an error term e(t) is desired to be minimized. In some systems, this approach can be represented as:

$$u(t) = K_p e(t) + K_i \int_0^{\tau} e(\tau)\,d\tau + K_d \frac{de(t)}{dt}$$

[0006] The first term represents the "P" (proportional) term, and is indicative of present error value(s). The second term represents the "I" (integral) term and accounts for past error value(s). The third term represents the "D" (derivative) term, and accounts for future error value(s) based on the instantaneous rate of change of the error function e(t). Together, these terms allow a control system to minimize e(t) (and thus u(t)) as e(t) varies in any given system. Critical to this approach, however, are the constants K_p, K_i, and K_d, which are scaling factors for each of the terms, and which must be determined with relative precision for the feedback process to work accurately.

[0007] Typically, scaling factors of a negative feedback control system, such as a PID controller, are derived from a process of trial and error. Some related arts use manual tuning that requires experienced engineering personnel, while others adopt heuristic tuning methods, such as Ziegler-Nichols, Cohen-Coon and/or Astrom-Hagglund as in the case of PID controllers. However, related arts are limited by the inherent limitations of feedback mechanisms including constant scaling parameters and no tuning of the feedback control system with respect to the final application area. Therefore, the overall performance of the feedback control system may not be optimal. This is seen typically with PID controllers wherein the feedback control system does not react to changing conditions or sudden events typically seen in vehicles that are aerial, terrestrial, oceanic and/or space-based. Vehicles, in the course of various applications, typically encounter changing conditions or sudden events due to a multitude of factors, including but not limited to, weather, obstacles, turbulence, noise, decrease in fuel, low visibility, irregular terrain, and so forth.

[0008] It may therefore be beneficial to provide a control system and/or method for use with a vehicle that address at least one of the above issues. For example, it may be beneficial to provide a control system facilitating an autopilot feature in a vehicle that operates with minimal system failures.

[0009] It may also be beneficial to provide control system and/or method for use with a vehicle wherein a step function **302** is selectively applied to one or more untuned or incorrectly tuned PID circuits in the system while keeping each of the other PID control circuits operational.

[0010] Some embodiments are directed to a system for use with a vehicle, the system including a plurality of control circuits for controlling an operation of the vehicle, each of the plurality of control circuits implementing one or more autopilot coefficients. The system further includes a sensor that is configured to detect one or more control circuits operating in an untuned or incorrectly tuned state from the plurality of control circuits; an electronic switch that is configured to isolate the one or more control circuits in the untuned or incorrectly tuned state from other control circuits; a tuning circuit that is configured to determine tuned values of the autopilot coefficients corresponding to the one or more control circuits in the untuned or incorrectly tuned state; the tuned values of the autopilot coefficients enabling the or more control circuits to operate in a tuned state; and a memory to store the tuned values of the autopilot coefficients, wherein the electronic switch is further configured to connect the one or more control circuits in the tuned state to the other control circuits.

[0011] Some other embodiments are directed to an unmanned vehicle for use with a companion unmanned vehicle, the unmanned vehicle including a plurality of control circuits for controlling an operation of the unmanned vehicle, each of the plurality of control circuits implementing one or more autopilot coefficients. The unmanned vehicle further includes a sensor that is configured to detect one or more control circuits operating in an untuned or incorrectly tuned state from the plurality of control circuits; an electronic switch that is configured to isolate the one or more control circuits in the untuned or incorrectly tuned state from other control circuits; a tuning circuit that is configured to determine tuned values of the autopilot coefficients corresponding to the one or more control circuits in the untuned or incorrectly tuned state, the tuned values of the autopilot coefficients enabling the one or more control circuits to operate in a tuned state; and a memory to store the tuned values of the autopilot coefficients, wherein the electronic switch is further configured to connect the one or more control circuits in the tuned state to the other control circuits.

[0012] Yet other embodiments are directed a method to controlling a vehicle operatively coupled to a controller, the vehicle having a plurality of control circuits, the method including detecting, by a controller, one or more control circuits operating in an untuned or incorrectly tuned state from the plurality of control circuits, each of the plurality of control circuits implementing one or more autopilot coefficients to control an operation of the vehicle; isolating, by an electronic switch, the one or more control circuits in the untuned or incorrectly tuned state from other control circuits; determining, by a tuning circuit, tuned values of the autopilot coefficients corresponding to the one or more control circuits in the untuned or incorrectly tuned state, the tuned values of the autopilot coefficients enabling the or more control circuits to operate in a tuned state; storing the tuned values of the autopilot coefficients; and connecting, by the electronic switch, the one or more control circuits in the tuned state to the other control circuits.

BRIEF DESCRIPTION OF DRAWINGS

[0013] The foregoing and other aspects of the embodiments disclosed herein are best understood from the following detailed description when read in connection with the accompanying drawings. For the purpose of illustrating the embodiments disclosed herein, there is shown in the drawings embodiments that are presently preferred, it being understood, however, that the embodiments disclosed herein are not limited to the specific instrumentalities disclosed. Included in the drawings are the following figures:

[0014] FIG. **1** is a schematic of a plurality of vehicles in accordance with the disclosed subject matter.

[0015] FIG. **2** illustrates components of one of the vehicles in accordance with the disclosed subject matter.

[0016] FIG. **3** is a schematic illustrating the application of a step function **302** to an isolated control circuit.

[0017] FIG. **4** is a method of controlling a vehicle having multiple control circuits in accordance with the disclosed subject matter.

[0018] FIG. **5** is a method to determine autopilot parameters in accordance with the disclosed subject matter.

[0019] 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

[0020] 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. Unmanned and Optionally-Manned Vehicles

[0021] FIG. **1** is a schematic of a system **100** having a plurality of unmanned vehicles **102***a* to **102***n* (hereinafter vehicle **102**), working in conjunction with each other.

[0022] The 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, an unmanned space vehicle, an unmanned aquatic or oceanic vehicle, a drone, a gyrocopter etc. In fact, embodiments are intended to include or otherwise cover any type of unmanned vehicle that may stay geostationary in the sky and also fly at a considerable height near and/or above inspected target or region of interest. The 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 other embodiments, the vehicle **102** and embodiments are intended to include or otherwise cover any type of optionally manned/piloted vehicle, including optionally manned/piloted vehicles operating in air (aircrafts), water, space and land (driverless cars).

[0023] In some embodiments, the vehicle **102** can be manually controlled by an operator present at a base station **104**. Communication between the vehicle **102** and the base station **104** may be established through a network **106**. In some other embodiments, the vehicle **102** may be autonomously controlled based on a predetermined control strategy. In yet other embodiments, the 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**. In yet other embodiments, the vehicles **102** may be part of a network and can communicate with each other. Systems and methods disclosed enable multiple vehicles to coordinate their operations or mission objectives with minimum interference with each other.

[0024] In some embodiments, the vehicles **102** can be facilitated with manual piloting/driving options along with an autopilot unit with the pilot/driver being able to view the operations of the autopilot through a display or the like. If necessary, the pilot/driver may choose to manually operate the vehicle. For example, the pilot/driver may manually operate the vehicles **102** in case of any hardware and/or software faults that may impede autonomous operation of the vehicles **102**.

[0025] For operating purposes, the vehicle **102** and its components (not shown) can be powered by a power source to provide propulsion. The power source can be, but is not restricted to, a battery, a fuel cell, a photovoltaic cell, a combustion engine, fossil fuel, solar energy, and so forth. Embodiments are intended to include or otherwise cover any type of power source to provide power to the unmanned vehicle for its operations.

[0026] In some embodiments, the vehicle **102** can have various components, such as, but not restricted to, rotors, propellers, flight control surfaces etc. that control movements and/or orientation of the vehicle **102**, and the like. Embodiments are intended to include or otherwise cover any other component that may be control movements and/or orientation of the vehicle **102**.

[0027] Further, in some embodiments, the unmanned vehicle **102** can also include but is not restricted to a processor, a memory, and the like. In some embodiments, the processor of the unmanned vehicle **102** can be a single core processor. In alternate embodiments, the processor can be a multi-core processor. Embodiments are intended to include or otherwise cover any type of processor, including known, related art, and/or later developed technologies to enhance capabilities of processing data and/or instructions. 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.

[0028] In some other 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 some embodiments, the communication network **106** may include or otherwise cover networks or subnetworks, each of which may include, for example, a wired or wireless data pathway. The communication network **106** may include a circuit-switched voice network, a packet-switched data network, or any other network capable for carrying electronic communications. For example, the network may include networks based on the Internet protocol (IP) or asynchronous transfer mode (ATM), and may support voice using, for example, VoIP, Voice-over-ATM, or other comparable protocols used for voice data communications. In one implementation, the network includes a cellular telephone network configured to enable exchange of text or SMS messages.

[0029] Examples of the communication network **106** may include, but are not limited to, a personal area network (PAN), a storage area network (SAN), a home area network (HAN), a campus area network (CAN), a local area network (LAN), a wide area network (WAN), a metropolitan area network (MAN), 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 vehicles **102** and/or the base station **104**.

II. Functioning of Autopilot Systems

[0030] FIG. **2** is a schematic of the vehicle **102** with its components. The vehicle **102** includes an autopilot unit **202**, a sensor **204**, an actuator **208** and a communication unit **210**. The autopilot unit **202** further includes a plurality of control circuits **212**, a plurality of electronic switches **216**, each of which is linked to each of the control circuits **212**, a controller **214**, a tuning circuit **218** with a signal function generator, and a memory **220**.

[0031] In some embodiments, the controller **214** retrieves pre-stored instructions from the memory **220** to implement any preset operations of the vehicle **200**. The preset operations may include navigating between two known points or in a known terrain, providing automatic steering control, correcting balance of the vehicle **102** under known weather conditions or any other potential adverse conditions. The memory **220** may also store pre-determined conditions or autopilot parameters for various potential events that may occur during operation of the vehicle **102**. The autopilot unit **202** uses a plurality of control circuits **212** to maintain the course for the vehicle **102**. Additionally, the controller can also use data obtained from the sensor **204** to incorporate corrections in the overall operation of the autopilot unit. In some embodiments, the sensor **204** can include multiple sensor units, such as, but not limited to, an inertial measurement unit (IMU), navigation unit(s), chip(s) incorporating receivers for the Global Positioning System (GPS) and/or Global Navigation Satellite System (GNSS), heading sensor(s), pressure sensor(s), accelerometer(s), altimeter(s) and so forth.

[0032] In an example, the autopilot unit **202** uses the plurality of control circuits **212** to provide a feedback to counteract an undesired change in roll, yaw and/or pitch of the vehicle. The undesired change can be detected by the sensor **204** with a detection signal. The sensor **204** may further communicate the detection signal coupled with data pertaining to the change to the control circuits **212**. Subsequently, the control circuits **212** generate a feedback signal for correcting the change and provide an output. The controller **214** directs the actuator **208** to implement the correction to correct the undesired change. In some embodiments, the actuator **208** can include servo motors, stepper motors, landing gears, rudders, rotors, engine controllers, elevator servo, aileron servo, flap servo, brakes, accelerators, power controllers and the like. In some embodiments, the control circuits **202** are configured to regulate a flight control surface of the vehicle **102**.

[0033] In some embodiments, the control circuits **212** include multiple Proportional Integral Differential (PID) controllers. Typically, PID controllers are directed by values of three coefficients namely K_p (proportional coefficient), K_i (integral coefficient) and K_d (differential coefficient). The PID controller calculation involves the aforementioned coefficients. The proportional value determines the correction of current error, the integral value determines correction for a sum of past errors, and the differential value calculates the correction for potential errors. By tuning the PID controllers, i.e., estimating the value of the three coefficients, the PID controllers can provide course corrections for specific errors or for specific events occurring during the operation of the vehicle. The tuning circuit **218** provides the tuning for the control circuits **212**. The PID controller coefficients are hereinafter to be termed as the autopilot coefficients or autopilot parameters.

[0034] In some embodiments, the PID controllers or control circuits **212** may not use all the coefficients at one time but use sets of one or any two coefficients as part of a control strategy. Some applications or operations of the vehicle **102** may require only the proportional value to determine a correction. Other applications may require the proportional and integral values or the proportional and differential values for correction. For example, applications or vehicle operations pertaining to linear motion typically require only the proportional value to determine course correction. In case of aerial vehicles facing turbulent weather conditions, all three coefficients may be required to determine correction. This is also apparent in the case of course correction in all three axes of yaw, pitch and roll.

[0035] In some embodiments, the control circuits **212** are tuned for preset and/or pre-determined events or conditions. Furthermore, in applications that require multiple PID controllers, individual PID controllers may be selected while the vehicle is in operation to be individually tuned (or calibrated) while the remaining PID controllers are left in their normal operating state, minimizing the danger of a vehicle collision or other critical malfunction during vehicle operation. Subsequently, a newly tuned (or calibrated) PID controller may be allowed to operate in its newly tuned state while a different PID controller is selected for tuning.

[0036] The preset tuned parameters (hereinafter termed as autopilot parameters) corresponding to specific events or conditions are stored on the memory **220** and are retrieved by the controller **214** when the sensor **204** detects the specific event and/or conditions. For example, for an aircraft or an aerial unmanned vehicle traversing a path that is subject to frequent winds in a particular direction, the sensor **204** can detect the presence of wind and initiates a control strategy to counteract the effect of the wind on the vehicle operation. The controller **214** retrieves autopilot parameters pertaining to this specific condition which is preset and applies them to the control circuits which in turn provide an error correction counteracting the wind.

[0037] In some embodiments, the autopilot parameters for preset conditions may be incorporated as a range of values. The controller **214** determines if the plurality of control circuits **212** operate in a tuned state at one or more of the preset ranges of values stored in the memory **220**. In some embodiments, the tuning circuit **218** adjusts the autopilot parameters or autopilot coefficients within a predetermined range.

[0038] One or more control circuits among the plurality of control circuits **212** can also be detected by the controller **214** and/or the tuning circuit **218** to not be operating in a tuned state when the vehicle faces unforeseen events or operation conditions resulting in a process equation not equivalent to the preset and/or predetermined parameters stored in the memory **220**. In some embodiments, the controller **214** can detect one or more untuned or incorrectly tuned control circuits based on data retrieved from the sensor **204** that shows that correction incorporated by the feedback from the corresponding control circuits **212** does not counteract the error in vehicle operation. In yet other embodiments, the tuning circuit **218** determines if the one or more control circuits corresponding to the autopilot coefficients operate in a tuned state at one or more of the adjusted values of the autopilot coefficients. Subsequently, the controller **214** isolates the untuned or incorrectly tuned control circuits by disabling the corresponding electronic switch **216** to each of the untuned or incorrectly tuned control circuit **212**. The control circuits **212** determined to be in the tuned state, are operated by the controller **214** or can be operated manually. The autopilot unit **202** in such a scenario relinquishes control to the pilot. In some embodiments, the pilot may control the vehicle **102** via the controller **214**. The pilot may be a separate control system or a human operator. In other embodiments, the controller **214** directs the communication unit **210** to transmit a signal to the base station **104** enabling the base station **104** to pilot the vehicle **102**. In yet another embodiment, the pilot may be a human pilot with the autopilot unit **202** switching to a manual mode. In some embodiments, that require multiple PID controllers, individual PID controllers are alternately selected for tuning while other control circuits **212** are maintained in their current states such that tuning can take place during vehicle operation.

[0039] In some embodiments, the switch **216** may be a single electronic switch connected serially to the plurality of control circuits **212**. In other embodiments, the switch **216** may be a plurality of electronic switches, each switch connected serially to each of the plurality of control circuits **212**. In yet other embodiments, the switch may be any conventional switching circuit facilitating automatic switching of one or more untuned or incorrectly tuned control circuits, the one or more untuned or incorrectly tuned control circuits being either manually programmed for tuning, or being detected by the controller **214** to be among the plurality of control circuits **212**. In case of the control circuits which are to be operated by the controller, the pilot or the base station **104**, the switch **216** is kept closed ensuring normal operation of the control circuits. The switch may be disabled for the untuned or incorrectly tuned control circuits. The switch **216** may be brought back to a neutral mode at the end of the tuning process.

[0040] FIG. **3** illustrates the tuning of an isolated untuned or incorrectly tuned control circuit **212**A that is one of the plurality of control circuits **212**.

[0041] Tuning mechanisms implemented can include the application of a step function **302** to the untuned or incorrectly tuned control circuit or PID controller **212**A. The step function **302** is generated by a tuning circuit **218** which is the same as the tuning circuit **218**. The tuning circuit **218** is configured to adjust at least one of duration, delays, step magnitude, step polarity, and a number of steps attributed to the step function **302**. The output response from the PID controller or control circuit **212**A can be further transmitted to a simulator **304**, or may be detected by any other means. The tuning circuit **218** can further adjust the step function **302** based on a response of the step function (say, from the simulator **304**, or by one or more sensors operating during the vehicle's operation). This step test allows for the determination of control parameters such as an operation gain, an operation dead time and an operation time constant attributed to the specific application or process equation. This test can also be used to determine the PID control parameters K_p, K_i, and K_d.

[0042] Dead time is the delay from when the output of the control circuit **212** is issued until when the controller **214** begins to respond. In some embodiments, a high value of dead time may also be used by the controller **214** to detect the untuned or incorrectly tuned state of one or more control circuits among the control circuits **212**. The operation time constant describes the speed of response to a change detected and transmitted by the sensor **204**. The operation gain describes the amount of change occurring in the vehicle operation to a change attributed to unforeseen events faced by the vehicle **102**. Upon determination of these values from the step response, established tuning methods such as Ziegler-Nichols, Cohen-Coon, Tyreus-Luyben, Astrom-Hagglund and/or dedicated software tools for tuning may be used by the controller **214** to estimate the appropriate autopilot parameters K_p, K_i and K_d. In some embodiments, the base station **104** may direct the controller to use the aforementioned tuning methods. In yet another embodiment, upon determination of these values, manual tuning may also be implemented by a pilot.

[0043] In FIG. **3**, the simulator **304** is a set of information sets, codes and/or instructions stored on the memory **220** imitating the vehicle operation. By mimicking the vehicle operation and using the control circuit **212**A, the corresponding operation gain, operation dead time and operation time constant are determined. In some embodiments, simulated results may be transmitted by the controller **214** to a display. The display (not shown) may be included as part of the vehicle **102** or at the base station **104**, in which case simulated results may be transmitted to the base station **104** via the communication unit **210**. The simulator **304** can typically reproduce the characteristics of the vehicle **102** in an environment defined by the data retrieved from the sensor **204**. The sensor data corresponds to the event or external conditions faced by the vehicle wherein one or more untuned or incorrectly tuned control circuits among the plurality of control circuits **212** are detected by the controller **214**. These results may also be determined directly by sensors or processors on the vehicle itself.

[0044] Iterations of the application of the step function **302** are done to determine a range of values for the autopilot coefficients upon successful implementation in the simulator **304** and to adjust the autopilot parameters or autopilot coefficients for the operation of the vehicle **102**. The determined autopilot parameters or autopilot coefficients are stored in the memory **220** and retrieved when similar events or external conditions are detected by the sensor **204** and/or the controller **214**.

III. Determination of Autopilot Parameters

[0045] FIG. **4** illustrates a method **400** to implement a tuning strategy for control the 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 for inspecting an object by using an unmanned vehicle.

[0046] In accordance with the flowchart of FIG. **4**, at step **402**, the control circuits among the plurality of control circuits **212** are detected by the controller **214** and/or the tuning circuit **218** to not operate in a tuned state when the vehicle faces unforeseen events or operation conditions. In some embodiments, the controller **214** can detect one or more untuned or incorrectly tuned control circuits based on data retrieved from the sensor **204** that shows that correction incorporated by the feedback from the corresponding control circuits **212** does not counteract the error in vehicle operation. In yet other embodiments, the tuning circuit **218** determines if the one or more control circuits corresponding to the autopilot coefficients operate in a tuned state at one or more of the adjusted values of the autopilot coefficients.

[0047] At step **404**, the controller **214** isolates the untuned or incorrectly tuned control circuits **202** by disabling the corresponding electronic switch **216** to each of the untuned or incorrectly tuned control circuit **212**. The control circuits **212** determined to be in the tuned state, are operated by the controller **214** or can be operated manually.

[0048] At step **406**, the values of autopilot parameters are determined by the application of step function **302** by the tuning circuit **218** and established tuning methods such as Ziegler-Nichols, Cohen-Coon, Tyreus-Luyben, Astrom-Hagglund and/or dedicated software tools for tuning may be used by the controller **214** to estimate the appropriate autopilot parameters K_p, K_i and K_d. Over multiple iterations, the tuning circuit adjusts at least duration, delays, step magnitude, step polarity and a number of steps of the step function to obtain a range of values of the autopilot coefficients.

[0049] At step **408**, the determined autopilot coefficients are used to operate the untuned or incorrectly tuned control circuits **202**. In some embodiments, the control circuits **202** use the determined autopilot coefficients to regulate a flight control surface of the vehicle **102**.

[0050] At step **410**, the isolated control circuits are reconnected to the other control circuits **202**. The determined autopilot coefficients are stored in the memory **220** for future use.

[0051] FIG. **5** is a flowchart of a method **500** for selectively applying a step function **302** to the isolated control circuit **212**A and subsequently tuning the control circuit **212**A to determine the most appropriate ranges of autopilot parameters or autopilot coefficients enabling the autopilot unit **202** to function when faced with unforeseen events during the course of the operation of vehicle **102**.

[0052] In accordance with the flowchart of FIG. **5**, the method **500** of tuning an isolated untuned or incorrectly tuned control circuit **212**A that is one of the plurality of control circuits **212** is described. At step **502**, the tuning circuit **218** applies a step function **302** to the isolated control circuit **212**A. The step function **302** is generated by a tuning circuit **218** which is the same as the tuning circuit **218**. The tuning circuit **218** is configured to adjust at least one of duration, delays, step magnitude, step polarity, and a number of steps attributed to the step function **302**. The output response from the PID controller or control circuit **212**A is further transmitted to a simulator **304** or other hardware or software detecting/processing elements. The tuning circuit **218** further adjusts the step function **302** based on response of simulator **304**. This step test allows the determination of control parameters such as operation gain, operation dead time and operation time constant. attributed to the specific application or process equation.

[0053] At step **504**, the step response is applied to a simulator **304**. The simulator **304** is a set of information sets, codes and/or instructions stored on the memory **220** imitating the vehicle operation. The corresponding operation gain, operation dead time and operation time constant are determined during the course of simulation. In some embodiments, the simulated results may be transmitted by the controller **214** to a display. The display (not shown) may be included as part of the vehicle or at the base station **104**, in which case simulated results may be transmitted to the base station **104** via the communication unit **210**. The simulator **304** typically reproduces the characteristics of the vehicle **102** in an environment defined by the data retrieved from the sensor **204**. The sensor data corresponds to the event or external conditions faced by the vehicle wherein one or more untuned or incorrectly tuned control circuits among the plurality of control circuits **212** are detected by the controller **214**. The simulated output response may be iteratively determined by feeding back changes in the step function **302**. In some embodiments, the simulated output may be compared to a reference state at the base station **104** or the controller **214**.

[0054] At step **506**, the autopilot coefficients are determined and appropriate adjustments are made. The simulated output is accepted when the error or dead time is below a tolerance value. Iterations are repeated until the values of autopilot coefficients are within a tolerance range.

[0055] At step **510**, the determined autopilot coefficients are stored in the memory **220** and retrieved when similar events or external conditions are detected by the sensor **204** and/or the controller **214**.

[0056] At step **512**, the switch **216** is enabled such that the isolated control circuits among the plurality of control circuits **212** function along with the other components of the vehicle **102**.

IV. Exemplary Embodiments

[0057] In accordance with disclosed subject matter, an exemplary scenario includes a plurality of vehicles **102** working in conjunction with each other and determining the autopilot coefficients without interrupting their operation. The plurality of vehicles **102** may be tasked to navigate as a coordinated group along a planned trajectory. The memory **220** on each of the vehicles **102** is stored with data relating to the task at hand such as the past, present and future locations of each of the vehicles, the path information, locations at which a steering action is required and so forth. The control circuits **212** on each of the vehicles employ corrective control strategies based on the stored data corresponding to the task and data from the sensor **204**. Accordingly, the tuning circuit **218** on each of the vehicles **102** adjusts the autopilot coefficients within a pre-determined range as defined by data stored on the memory **220**. If any change sensed by the sensor **204** that corresponds to preset conditions stored on the memory **220**, the autopilot parameters are appropriately adjusted by the tuning circuit **218** to counteract the change. For example, the change can arise due to an expected turn or steering action at a specific location. The change can be detected by the sensor **204** on one or more vehicles **102**. Accordingly, the control circuits **212** on the vehicles that have detected the change employ corrective control strategies by adjusting the autopilot coefficients via the controller **214** and/or the tuning circuit **218**. The communication unit **210** can communicate to the rest of the vehicles **2012** and/or the base station **104** data corresponding to the change and the corrective control strategy employed. Accordingly, the rest of the vehicles **102** can determine if similar control strategies need to be employed and execute similar actions respectively or the base station **104** can direct the rest of the vehicles **102** to employ similar corrective control strategies by appropriate adjustment of autopilot parameters.

[0058] The plurality of vehicles **102** can face unforeseen events such as turbulent weather conditions. Resultant changes are detected by the sensor **204** on each of the vehicles **102**. Alternately, the base station **104** or at least one of the plurality of vehicles **102** can detect an unforeseen event and communicate corresponding data or information to the rest of the plurality of vehicles **102**. In accordance with the disclosed subject matter, the detection of an unforeseen event can also occur due to the dead time, control gain and/or time constant deviating from a permissible or tolerable range of values. Subsequently, the controller **214** disables the switches **216** of one or more control circuits **212** that are out of tune with the desired autopilot coefficients. The rest of the control circuits may operate normally and can be remotely operated by the base station **104** or the controller **214** or a human pilot such that the vehicles **102** are on course.

[0059] A step function **302** is applied to the one or more untuned or incorrectly tuned control circuits **212** with disabled switches **216** by the tuning circuit **218**. The tuning circuit **218** is configured to adjust at least one of duration, delays, step magnitude, step polarity, and a number of steps attributed to the step function **302**. The output response from the PID controller or control circuit **212**A is further transmitted to a simulator **304**. The tuning circuit **218** further adjusts the step function **302** based on response of simulator **304**. This step test allows the determination of control parameters such as an operation gain, an operation dead time and an operation time constant attributed to the specific application or process equation. Upon determination of these values from the step response, established tuning methods such as Ziegler-Nichols, Cohen-Coon, Tyreus-Luyben, Astrom-Hagglund and/or dedicated software tools for tuning may be used by the controller **214** to estimate the appropriate autopilot parameters K_p, K_i and K_d. In some embodiments, the base station **104** may direct the controller **214** to use the aforementioned tuning methods. In yet another embodiment, upon determination of these values, manual tuning may also be implemented by a pilot. The determined autopilot parameters or autopilot coefficients are stored in the memory **220** and retrieved when similar events or external conditions are detected by the sensor **204** and/or the controller **214**.

[0060] Subsequently, upon determination and storing of the autopilot parameters, the isolated control circuits **212** resume operation. The new values may be communicated to other vehicles **102** via the communication unit **210**. Based on the new values of autopilot coefficients, the other vehicles **102** may undergo similar tuning processes to maintain the combined course of the plurality of vehicles **102**.

V. Other Exemplary Embodiments

[0061] FIG. **6** illustrates a computer system **600** upon which the operation of the controller **214**, tuning circuit **218**, control circuits **212** and switch **216** may be implemented. 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 system. The computer system **600** is programmed (e.g., via computer program code or instructions) to inspect the objects by using one or more vehicles described herein and includes a communication mechanism such as a bus **602** for passing information between other internal and external components of the computer system **600**. Information (also called data) is represented as a physical expression of a measurable phenomenon, typically electric voltages, but including, in other embodiments, such phenomena as magnetic, electromagnetic, pressure, chemical, biological, molecular, atomic, sub-atomic and quantum interactions. For example, north and south magnetic fields, or a zero and non-zero electric voltage, represent two states (0, 1) of a binary digit (bit). Other phenomena can represent digits of a higher base. A superposition of multiple simultaneous quantum states before measurement represents a quantum bit (qubit). A sequence of one or more digits constitutes digital data that is used to represent a number or code for a character. In some embodiments, information called analog data is represented by a near continuum of measurable values within a particular range. The computer system **600**, or a portion thereof, constitutes a means for performing one or more steps for inspecting the objects by using one or more vehicles.

[0062] 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**.

[0063] The processor (or multiple processors) **604** performs a set of operations on information as specified by computer program code related to inspect the objects by using one or more vehicles. 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.

[0064] 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.

[0065] Information, including instructions for inspecting the objects by using one or more vehicles 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; a pointing device **617**, 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.

[0066] 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.

[0067] 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 **622** for inspecting the objects by using one or more vehicles. 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.

[0068] 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.

[0069] 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**.

[0070] 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).

[0071] 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 **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**.

[0072] 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.

[0073] 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**.

V. Alternative Embodiments

[0074] While certain embodiments of the invention are described above, and FIGS. **1** to **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 scope of the invention.

[0075] Embodiments are disclosed above in the context of a vehicle and/or a group of vehicles. However, embodiments are intended to include or otherwise cover any type of vehicle including aircrafts, cars, ships, unmanned vehicle, gyrocopter, drone, optionally manned vehicle etc.

[0076] The vehicles **102** can be used to achieve a mission objective. For example, the vehicles **102** can also operate as a type of satellite (relaying data to and from communications equipment) to assess data rate transmission and thereby assess performance, damage, etc., of the communications equipment. Unmanned vehicle groups can use electronic assessments to selectively transmit/receive signals from different members of the swarm to perform precise directional analysis of signals,

[0077] Unmanned vehicles and vehicle groups can use electronic assessments to detect nonlinear signals, such as are produced in response to electronically pinging a nonlinear device (cell phone, laptop, router, walkie-talkie, etc.). Unmanned vehicles and vehicle swarms can use electronic assessments to detect changes in the atmosphere (such as the 60 GHz H_2O resonant frequency) to perform atmospheric analysis (i.e., ozone levels, pollution, glacial melting, organic growth (forest depletion), etc.). These devices are often used in the detonation of improvised explosive devices (IEDs). In each of the aforementioned applications, control strategies can be implemented to achieve the mission objectives. Preset data is used to initialize operations and upon detection of any unforeseen events during the course of the mission, control strategy is manipulated by the tuning methods as disclosed by the embodiments of the invention described in previous sections. New control parameters for untuned or incorrectly tuned control circuits are determined after isolating the untuned or incorrectly tuned control circuits and applying a step function **302** to these control circuits. The output response is transmitted to a simulator replicating the environment pertaining to the application or mission objective. A simulated environment is replicated by the use of retrieved data from sensors and the memory. This is done to simulate the unforeseen events during the course of the mission objective.

[0078] Exemplary embodiments are also intended to cover any additional or alternative components of the vehicle disclosed above. Exemplary embodiments are further intended to cover omission of any component of the vehicle disclosed above.

[0079] Exemplary embodiments are also intended to include and/or otherwise a v-formation of a fleet of unmanned vehicles, which can cause each of the unmanned vehicles to be well separated. However, embodiments of the disclosed subject matter are intended to include or otherwise cover any type of formation that may be beneficial.

[0080] Exemplary embodiments are also intended to include and/or otherwise use aircrafts with dedicated autopilot systems. The aircraft can be autonomously piloted using the autopilot system, the manual mode activated upon detection of untuned or incorrectly tuned control circuits. The untuned or incorrectly tuned control circuits are separated from the normal operation and are subject to a step response along with a tuning method (Ziegler-Nichols, Ziegler-Nichols, Cohen-Coon, Tyreus-Luyben, Astrom-Hagglund and/or dedicated software tools for tuning). Upon determination of appropriate autopilot parameters or autopilot coefficients, the autopilot system returns to normal operation. Such a process offers dynamic tuning of the control circuits **212** with minimal system failure or break in vehicle operation. By storing and retrieving the determined autopilot coefficients, the autopilot unit **202** is made adaptable.

[0081] Embodiments are also intended to include or otherwise cover methods of manufacturing the 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 vehicle disclosed above.

[0082] 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.

[0083] In accordance with the exemplary embodiments, the disclosed computer programs can be executed in many exemplary ways, such as an application that is resident in the memory of a device or as a hosted application that is being executed on a server and communicating with the device application or browser via a number of standard protocols, such as TCP/IP, HTTP, XML, SOAP, REST, JSON and other sufficient protocols. The disclosed computer programs can be written in exemplary programming languages that execute from memory on the device or from a hosted server, such as BASIC, COBOL, C, C++, Java, Pascal, or scripting languages such as JavaScript, Python, Ruby, PHP, Perl or other sufficient programming languages.

[0084] Some of the disclosed embodiments include or otherwise involve data transfer over a network, such as communicating various inputs over the network. The network may include, for example, one or more of the Internet, Wide Area Networks (WANs), Local Area Networks (LANs), analog or digital wired and wireless telephone networks (e.g., a PSTN, Integrated Services Digital Network (ISDN), a cellular network, and Digital Subscriber Line (xDSL)), radio, television, cable, satellite, and/or any other delivery or tunneling mechanism for carrying data. Network may include multiple networks or subnetworks, each of which may include, for example, a wired or wireless data pathway. The network may include a circuit-switched voice network, a packet-switched data network, or any other network able to carry electronic communications. For example, the network may include networks based on the Internet protocol (IP) or asynchronous transfer mode (ATM), and may support voice using, for example, VoIP, Voice-over-ATM, or other comparable protocols used for voice data communications. In one implementation, the network includes a cellular telephone network configured to enable exchange of text or SMS messages.

[0085] Examples of a network include, but are not limited to, a personal area network (PAN), a storage area network (SAN), a home area network (HAN), a campus area network (CAN), a local area network (LAN), a wide area network (WAN), a metropolitan area network (MAN), a virtual private network (VPN), an enterprise private network (EPN), Internet, a global area network (GAN), and so forth.

[0086] 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 system for use with a vehicle, comprising:

a plurality of control circuits for controlling an operation of the vehicle, each of the plurality of control circuits implementing one or more autopilot coefficients;

a first controller that is configured to tune one or more control circuits of the plurality of control circuits operating in an untuned or incorrectly tuned state;

an electronic switch that is configured to isolate the one or more control circuits in the untuned or incorrectly tuned state from other control circuits;

a tuning circuit that is configured to determine tuned values of the autopilot coefficients corresponding to the one or more control circuits in the untuned or incorrectly tuned state, the tuned values of the autopilot coefficients enabling at least one of the control circuits to operate in a tuned state;

a memory that is configured to store the tuned values of the autopilot coefficients;

an autopilot unit being formed by the plurality of control circuits, and at least one of the electronic switch, the tuning circuit, the first controller, and the memory;

a sensor connected to the autopilot unit for communicating with the autopilot unit; and

an actuator connected to the autopilot unit for receiving correctional directions from the autopilot unit;

wherein the electronic switch is further configured to connect the one or more control circuits in the tuned state, which were initially operating in the incorrectly tuned state, to the other control circuits,

wherein each of the plurality of control circuits is a Proportional Integral Derivative (PID) controller, wherein the autopilot coefficients, which correspond to each of the plurality of control circuits, are PID coefficients, and wherein the PID controller is a separate element than the first controller.

2. (canceled)

3. The system of claim **1**, wherein the tuning circuit sets is further configured to adjust values of each of the autopilot coefficients within a predetermined range; and

determine if the one or more control circuits corresponding to the autopilot coefficients operate in a tuned state at one or more of the adjusted values of the autopilot coefficients.

4. The system of claim **3**, wherein the tuning circuit is further configured to:

apply a step function to the one or more control circuits operating in the untuned or incorrectly tuned state; and

monitor outputs of the one or more control circuits, which operate in the unturned or incorrectly tuned state, correspond to the adjusted values of the autopilot coefficients.

5. The system of claim **4**, wherein the tuning circuit is further configured to adjust at least one of duration, delays, step magnitude, step polarity, and a number of steps of the step function.

6. The system of claim **1**, wherein the controller is further configured to operate the other control circuits during tuning of the one or more control circuits operating in the untuned or incorrectly tuned state.

7. The system of claim **1**, wherein at least one of the control circuits of the plurality of control circuits is configured to regulate a flight control surface of the vehicle.

8. A method for controlling a vehicle operatively coupled to a controller with the vehicle including a plurality of control circuits, the method comprising:

detecting, by a first controller, that one or more control circuits are operating in an untuned or incorrectly tuned state from the plurality of control circuits, each of the plurality of control circuits implementing one or more autopilot coefficients to control an operation of the vehicle;

isolating, by an electronic switch, the one or more control circuits in the untuned or incorrectly tuned state from other control circuits;

determining, by a tuning circuit, tuned values of the autopilot coefficients corresponding to the one or more control circuits in the untuned or incorrectly tuned state, the tuned values of the autopilot coefficients enabling the one or more control circuits to operate in a tuned state;

storing, in a memory, the tuned values of the autopilot coefficients; and

connecting, by the electronic switch, the one or more control circuits in the tuned state, which were initially operating in the incorrectly tuned state, to the other control circuits,

wherein each of the plurality of control circuits is a Proportional Integral Derivative (PID) controller, wherein the autopilot coefficients, which correspond to each of the plurality of control circuits, are PID coefficients, and wherein the PID controller is a separate element than the first controller.

9. The method of claim **8**, further comprising adjusting, by the tuning circuit, values of each of the autopilot coefficients within a predetermined range; and

determining, by the tuning circuit, if the one or more control circuits corresponding to the autopilot coefficients operate in a tuned state at one or more of the adjusted values of the autopilot coefficients.

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

applying, by the tuning circuit, a step function to the one or more control circuits operating in the untuned or incorrectly tuned state; and

monitoring, by the tuning circuit, outputs of the one or more control circuits, which operate in the untuned or incorrectly tuned state, correspond to the adjusted values of the autopilot coefficients.

11. The method of claim **10**, further comprising adjusting, by the tuning circuit, at least one duration, delays, step magnitude, step polarity, and a number of steps of the step function.

12. The method of claim **8**, further comprising operating, by the controller, the other control circuits during tuning of the one or more control circuits operating in the untuned or incorrectly tuned state.

13. The method of claim **8**, further comprising controlling, by at least one control circuit of the plurality of control circuits, a flight control surface of the vehicle.

14. An unmanned vehicle comprising:

a plurality of control circuits for controlling an operation of the unmanned vehicle, each of the plurality of control circuits implementing one or more autopilot coefficients;

a first controller that is configured to tune one or more control circuits operating in an untuned or incorrectly tuned state from the plurality of control circuits;

an electronic switch that is configured to isolate the one or more control circuits in the untuned or incorrectly tuned state from other control circuits;

a tuning circuit that is configured to determine tuned values of the autopilot coefficients corresponding to the one or more control circuits in the untuned or incorrectly tuned state, the tuned values of the autopilot coefficients enabling the or more control circuits to operate in a tuned state; and a memory that is configured to store the tuned values of the autopilot coefficients;

wherein the electronic switch is further configured to connect the one or more control circuits in the tuned state, which were initially operating in the incorrectly tuned state, to the other control circuits,

wherein each of the plurality of control circuits is a Proportional Integral Derivative (PID) controller, wherein the autopilot coefficients, which correspond to each of the plurality of control circuits, are PID coefficients, and wherein the PID controller is a separate element than the first controller.

15. (canceled)

16. The unmanned vehicle of claim **14**, wherein the tuning circuit is further configured to:

adjust values of each of the autopilot coefficients within a predetermined range; and

determine if the one or more control circuits corresponding to the autopilot coefficients operate in a tuned state at one or more of the adjusted values of the autopilot coefficients.

17. The unmanned vehicle of claim **16**, wherein the tuning circuit is further configured to apply a step function to the one or more control circuits operating in the untuned or incorrectly tuned state; and

monitor outputs of the one or more control circuits, which operate in the untuned or incorrectly tuned state, correspond to the adjusted values of the autopilot coefficients.

18. The unmanned vehicle of claim **17**, wherein the tuning circuit is further configured to adjust at least one duration, delays, step magnitude, step polarity, and a number of steps of the step function.

19. The unmanned vehicle of claim **14**, wherein the unmanned vehicle further comprises a communication unit that is configured to communicate with at least one of another unmanned vehicle and a base station.

20. The unmanned vehicle of claim **19**, wherein a controller of at least one of the another unmanned vehicle and the base station is configured to control the other control circuits of the another unmanned vehicle during tuning of the one or more control circuits operating in the untuned or incorrectly tuned state.

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