

SYSTEM AND METHOD FOR CONTROLLING AN AMPHIBIOUS VEHICLE

FIELD OF INVENTION

- 5 The invention relates to a system and method for controlling an amphibious vehicle. The invention is especially suited, but not limited to, the control of one or more hydraulic drives in an amphibious vehicle.

BACKGROUND ART

- 10 The following discussion of the background to the invention is intended to facilitate an understanding of the present invention. However, it should be appreciated that the discussion is not an acknowledgment or admission that any of the material referred to was published, known or part of the common general knowledge in any jurisdiction as at the priority date of the application.

- 15 Hydraulic systems have been widely used or adopted in different applications. Some typical applications include hydrostatic drive, crane, and winches for civil or military use.

- In some military amphibious vehicles, hydraulic drives are utilized for land movement and water propulsion. In a conventional amphibious vehicle driven by hydraulic-
20 drives, one or more hydraulic pumps may be arranged to drive two cooling fan motors and another two hydraulic pumps are arranged to drive two propeller motors (also referred to as swim propellers).

- As shown in Fig. 1, a conventional arrangement comprising a fan controller, a fan pump and two cooling fan motors may be regarded as the fan subsystem, and an
25 arrangement comprising a swim controller, two swim pumps and two swim propeller motors may be regarded as the swim subsystem. It is to be appreciated that the fan and swim subsystems are typically independent in the conventional arrangement. In land operation, the two cooling fan motors may be activated and be driven by the fan subsystem. In swim operation, the two swim propeller motors, and sometimes the two
30 cooling fans, are all activated and driven by the swim subsystem. Such an arrangement is however hardly space-efficient as redundancy is introduced. In addition, because of the independence of the two subsystems and controllers,

synchronization and/or timing circuits will need to be introduced into the fan and swim subsystems to ensure proper switching between the land operation and the swim operation.

In addition, the independent fan and swim subsystems are typically controlled via an open loop mechanism. Open-looped systems are generally unable or less able to take into account errors, sudden changes or track one or more desired outputs.

In conventional power management of the hydraulic system, different hydraulic pumps on the amphibious vehicle may continue to consume engine power even when not in use, thereby creating performance inefficiencies. If there is a need to add hydraulic pumps, a common solution is to upsize the engine (typically an internal combustion engine or ICE) to provide higher engine power/torque to meet the total power demand of the hydraulic system. However, such a solution increases cost, space and the overall weight or load of the amphibious vehicle.

There exists a need therefore to reduce the number of components to enhance space efficiency. There further exists a need to enhance the control of the hydraulic system to optimize and improve power efficiency.

SUMMARY OF THE INVENTION

There is envisaged a system and method of controlling an amphibious vehicle. The control mechanism includes a single controller, known as a Hydraulic Control Module (HCM) to eliminate the need for synchronization and communication between multiple controllers, and provides a modularized and scalable layered software architecture.

In accordance with an aspect of the invention there is a system for controlling an amphibious vehicle comprising a single controller arranged in signal communication with a plurality of inputs; and at least one drive arranged to receive a control signal from the single controller to drive a fan and/or a propeller motor; wherein the single controller is operable to provide the control signal based on at least one of the plurality of inputs, and the single controller comprises at least one module that is reusable; and wherein the single controller is operable to switch the amphibious vehicle between a land mode for movement on land and a swim mode for movement on a water body.

In some embodiments, the single controller is an electronic controller.

In some embodiments, the at least one drive is a hydraulic pump.

5 In some embodiments, the system comprises an isolation valve arranged between the at least one drive and the fan and/or propeller. In some embodiments, the single controller is operable to send a mode switch signal to the isolation valve to allow access for the drive to drive the propeller.

10 In some embodiments, the mode switch signal is a voltage signal to enable access to the drive or removal of the voltage signal to disable access to the drive.

In some embodiments, wherein the plurality of inputs comprises at least two of the following:-

15 at least one operator input; a plurality of sensors; and a Controller Area Network (CAN bus); to receive signals associated with at least one parameter of the amphibious vehicle in operation.

In some embodiments, the control signal is an electrical current or electrical voltage.

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In some embodiments, in order to drive the fan the control signal is dependent at least on temperature at specific locations of the amphibious vehicle and the current engine speed.

25 In some embodiments, in order to drive the propeller the control signal is dependent on an operator input.

In accordance with another aspect of the invention there is a method for controlling an amphibious vehicle comprising the steps of:

30 (a.) receiving at a single controller a plurality of inputs associated with the operating environment of the amphibious vehicle;

(b.) determining at the single controller a control signal based on the plurality of inputs;

(c.) sending the control signal from the single controller to a drive; the drive arranged to drive a fan and/or a propeller.

- 5 In some embodiments, the method further comprises the step of sending at least one control signal to enable or disable a swim isolation valve, preferably before step (c).

In some embodiments, step (b.) further comprises the step of receiving at least one temperature parameter of the operating environment of the amphibious vehicle,
10 receiving a speed parameter of the engine of the amphibious vehicle, and receiving a predetermined duration of past control signal as feedback.

In accordance with another aspect of the invention there is an electronic controller for controlling an amphibious vehicle to switch the amphibious vehicle between a land
15 mode for movement on land and a swim mode for movement on a water body, wherein the electronic controller may be arranged in signal communication with an isolation valve, the isolation valve in turn arranged to enable and disable access to a plurality of drives, wherein a first drive of the plurality of drives is associated with the land mode and a second drive of the plurality of drives is associated with the swim
20 mode; and wherein the electronic controller is operable to send a mode switch signal to the isolation valve to switch between the land mode and the swim mode.

In some embodiments, the mode switch signal is a voltage signal to enable access to the second drive or the removal of the voltage signal to disable access to the
25 second drive.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described, by way of example only, with reference
30 to the accompanying drawings, in which:

Fig. 1 is a prior art arrangement for controlling an amphibious vehicle;

Fig. 2 is a system block diagram of the system for controlling an amphibious vehicle in accordance with some embodiments;

Fig. 3a is a control block diagram for controlling an amphibious vehicle in land mode;

Fig. 3b is a control block diagram for controlling an amphibious vehicle in swim mode;

5 Fig. 4 shows a software architecture of the control unit according to some embodiments of the invention;

Fig. 5 is a flow chart depicting the operation of the amphibious vehicle; and

Fig. 6 shows a state machine diagram of the control flow between land mode and swim mode according to some embodiments of the invention.

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DETAILED DESCRIPTION

It is to be appreciated that the term 'control signal' used throughout the description may refer to an electrical, electronic signal to activate a drive, such as a hydraulic pump, or a signal to regulate the hydraulic flow produced by the drive.

15 Throughout the description, the term 'fan' and 'propeller' may include the relevant drive(s) associated with the fan or propeller to power the said fan or propeller. Such drive may be in the form of a motor, pump etc.

Throughout the description, the term 'amphibious vehicle' may include, but are not limited to vehicles such as all-terrain vehicles (ATVs), buses, trucks, hovercrafts,
20 boats, cargo vehicles, military personnel carriers, military tanks.

According to an aspect of the invention, there is a system for controlling an amphibious vehicle comprising a single controller arranged in signal communication with a plurality of inputs; and at least one drive arranged to receive a control signal from the single controller to drive a fan and/or a propeller; wherein the single controller
25 is operable to provide the control signal based on at least one of the plurality of inputs as feedback, and the single controller comprises at least one module that is reusable.

The single controller is comprises control logic to switch the amphibious vehicle between a land mode for movement on land and a swim mode for movement on a water body In some embodiments, the at least one drive may be in the form of one or
30 more hydraulic pumps.

With reference to Fig. 2, the system 20 comprises a central controller 22, also referred to as a hydraulic control module (HCM) 22 arranged in signal and/or data

communication with a plurality of inputs 24. The central controller 22 operates to process the plurality of inputs 24 to produce a first control signal 202 to control a first hydraulic pump 26 and a second control signal 204 to control a second hydraulic pump 28. Depending on the value of the corresponding control signals, the first
5 hydraulic pump 26 and second hydraulic pump 28 will produce corresponding hydrostatic or hydrodynamic force to drive one or more cooling fans and swim propellers. In some embodiments where the first and/or second hydraulic pump comprise one or more swash plates, the control signals, which can be in the form of electrical voltage or current may be used to adjust the swash plate angle of the first
10 hydraulic pump 26 and/or second hydraulic pump 28 to regulate the hydraulic flow to drive one or more cooling fan or swim propeller motors.

In some embodiments, the central controller 22 further operates to send a third control signal 206 and a fourth control signal 208 to a swim isolation valve 30. The third and fourth control signal may also be referred to as mode switch signals. The third control
15 signal 206 and the fourth control signal 208 may be 'enable' and 'disable' signals respectively to enable and disable the swim mode of the amphibious vehicle. These control signals 206 and 208 may be sent before the first control signal 202 and/or second control signal 204 are sent to the first and second hydraulic pump respectively.

20 In some embodiments, the control signal 206 is an electrical voltage to enable the isolation valve 30, and the control signal 208 is a zero or cut-off voltage to disable the isolation valve 30. The swim isolation valve 30 is connected in a fluid path or in hydraulic connection with the cooling fan motors 34, 38 and swim 36, 40. When the swim mode is enabled, the swim isolation valve 30 operates to isolate the hydraulic
25 flow from the cooling fans 34, 38 and allow hydraulic flow to the swim propellers 36, 40. When the swim mode is disabled, the swim isolation valve 30 operates to isolate the hydraulic flow from the swim propeller 36, 40 and allow hydraulic flow to operate the cooling fans 34, 38. In some alternative embodiments, when the swim mode is enabled, there is no isolation of the hydraulic pumps from the cooling fan motors 34,
30 38.

The hydraulic control module 22 may be an electronic controller or microcontroller having hardware memory modules such as Read-Only memory (ROM) modules

and/or Random Access Memory (RAM) modules, one or more programmable modules for implementing control logic, and input module comprising input management hardware and software such as, but not limited to analogue to digital convertors (ADC), digital to analogue convertors (DAC), task schedulers, fault management module. In some embodiments, the electronic controller may be an application specific integrated circuit (ASIC) or other types of integrated circuits. In some embodiments, the HCM 22 may be a real time processor chip operable to run different processing threads in a multithread environment.

The plurality of inputs 24 comprise operator signals obtained from an operator or user interface 24a, a plurality of sensors 24b, and inputs 24c from a Controller Area Network (CAN bus) arranged in signal or data communication with the hydraulic control module 22 to communicate with each other. Inputs 24c may comprise an electronic display interface panel (eDIP), electronic control units (ECU), transmission control module (TCM) and vehicle power unit (VPU). From the various inputs 24c, the following information, in the form of data signals, may be retrieved:-

- a. intake manifold temperature;
- b. coolant temperature;
- c. transmission oil temperature; and/or
- d. engine speed.

In some embodiments, the operator signals may include a joystick, and a swim mode switch.

Although the CANbus signals have been indicated in the drawings to be unidirectional, it is to be appreciated that the CANbus signals can be bidirectional, i.e. the HCM 22 can interact with the CANbus for exchange of data, signals, and/or information. In some embodiments, the HCM 22 can also interact with one or more electronic control units (ECU) arranged in data communication with the CANbus to exchange information or send command or control signal to the one or more ECU to perform specific functions associated with the control of various aspects of the amphibious vehicle, such as, for example, activation of ramp where available, deployment of trim vane, activation of auxiliary power unit(s) etc.

The plurality of sensors 24b may include two or more of the following type of sensors:- electrical current sensor, electrical voltage sensor, electrical power sensor,

temperature sensor, pressure sensor, cooling fan speed sensor and hydraulic motor speed sensor, hydraulic oil level sensor, pump displacement sensor, flowmeter etc. The various temperature parameters obtained from the CANbus (some of which can be sensed via one or more temperature sensors) may include an intake manifold temperature, a coolant temperature, a transmission oil temperature, and a hydraulic oil temperature. The plurality of sensors 24b may form part or whole of the feedback loop to the central controller 22.

With reference to Fig. 3a, which shows a control block diagram in the Laplace domain to control the first and/or second cooling fan 34, 38, the HCM 22 is arranged to receive a temperature input $U(s)$ and amphibious vehicle's engine speed input $E(s)$ as well as the output control electrical current $Y(s)$ as inputs and/or feedback. The activation signal in the form of an output electrical current $Y(s)$ is used to activate/drive the first and/or second hydraulic pump 26, 28 to drive the first and/or second cooling fan motor 34, 38. As a general control principle, the fan control is dependent on 'cooling demand' or the need to cool certain parts or units of the amphibious vehicle. This is directly correlated to the temperature of any of the aforementioned temperatures, that is, when any of the aforementioned temperature is sensed to increase, the cooling fan is activated to turn or turn at a higher speed.

In some embodiments, as one of the aforementioned temperature increase above a pre-determined threshold (hereinafter referred to as individual temperature threshold), the first and/or second cooling fan 34, 38 are activated if not already done so, or the fan speed of the first and/or second cooling fan 34, 38 are increased if the cooling fan has already been activated.

In some embodiments, weighted sum or weighted average of the aforementioned temperature may be computed/determined and compared with a pre-determined weighted sum or weighted average threshold (hereinafter referred to as group threshold). If the determined weighted sum or weighted average exceeds the group threshold, the first and/or second cooling fan 34, 38 are activated if not already done so, or the fan speed of the first and/or second cooling fan 34, 38 are increased if the cooling fan has already been activated.

With reference to Fig. 3b, which shows a control block diagram in the Laplace domain to control the first and/or second swim propellers 36, 40, the HCM 22 is arranged to

receive a user (joystick) input $J(s)$ and the output control electrical current $Y(s)$ as inputs and/or feedback. The activation signal in the form of an output electrical current $Y(s)$ is used to activate/drive the first and/or second hydraulic pump 26, 28 to drive the first and/or second swim propeller motors 36, 40.

5 In some embodiments, when the joystick is actuated, the corresponding control signal is sent to the first hydraulic pump 26 and/or the second hydraulic pump 28, as the case may be. For example, if the operator actuates the joystick to 'sharp turn left/right', control signals may be sent to the first hydraulic pump 26 to drive the second swim propeller 40 at a forward mode, and the first swim propeller 36 at a
10 reverse mode to achieve the sharp turn left/right direction as soon as possible. The forward or reverse mode of the swim propellers 36, 40 may be achieved by clockwise and anticlockwise rotations of the swim propellers 36, 40 depending on the angle and shape of the propeller blades as known to a skilled person.

It is to be appreciated that in the control block diagram of Fig. 3a and Fig. 3b, control
15 signals are sent by the HCM 22 to activate the swim isolation valve 30 to effect switching between the first cooling fan 34 and first swim propeller 36, switching between the second cooling fan 38 and second swim propeller 40. The swim isolation valve 30 may be operated between a number of modes so as to allow the first and second hydraulic pumps 26, 28 to drive the first/second cooling fan, the first/second
20 swim propeller, and/or combinations of the above.

In some embodiments, the control blocks for controlling the fans and propellers may be processed in parallel.

Fig. 4 shows an exemplary software architecture of the HCM 22 to implement the various functions and control logic to provide the necessary control signals and/or
25 output signals to drive the hydraulic pumps as well as to enable or disable the swim isolation valve 30. It is to be appreciated that such a software architecture comprises modules, such as the central processing unit (CPU), which can be running parallel processing threads, also known as multithreading. The CPU may be a single core, dual core, quadcore or any multicore CPU. In some embodiments, the hardware and
30 software of the HCM 22 may comprise multiple layers organized into hardware, drivers, application programming interface, common services, application configuration services, and application specific layer.

With a software architecture having multiple layers, scalability and modularity may be achieved. The software architecture comprises a controller hardware layer 402, a device driver layer 404, an application programming interface 406, a common services layer 408, an application configuration services layer 410, and an application specific layer 412.

In some embodiments, one or more propellers and/or hydraulic pumps (not shown) may be added to the system 20. In such an arrangement, the aforementioned software architecture may be scalable such that certain common software modules such as CPU, input management, control block module are reusable when the new hydraulic pumps are added to the overall system without the need to introduce new HCMs, thereby optimizing form factor.

In some embodiments, optimization of power management may be achieved via one or more of the following steps:-

- a. collection of power usage profiles in both land mode and swim mode operations by the HCM 22 over a period;
- b. analysing the collected power usage profiles to determine how hydraulic power is utilized or flowed in both land mode and swim mode;
- c. analysing the switching of isolation valve 30 between land mode and swim mode.

The collection of power usage profiles could be performed through the use of a data acquisition system or database.

Analysis of the collected power usage profiles can be performed via an artificial intelligence engine, which can be integrated with the HCM 22 or a separate module, with deep learning or machine learning capabilities, so as to extract relevant 'patterns' or 'signatures' associated with power usage during swim mode and/or land mode, for example switch on/off selected fans or propellers.

In some embodiments, there may further comprise a data analytic module arranged in data communication with the plurality of inputs to obtain data over a period and perform deep learning (e.g. via multiple layers of neural network) to optimize the control signals sent to the hydraulic pumps 26, 28.

In some embodiments, the HCM 22 may communicate with one or more inputs via wireless communication. Such an arrangement may further reduce the need for wired communication line(s) which increase form factor of the controller.

In some embodiments, the HCM 22 comprises a data acquisition system or module. Such data acquisition system or module may be in the form of one or more databases. In some embodiments, one or more types of information may be broadcasted by HCM 22. The broadcasted information may be collected/logged by the data acquisition system or module.

The system 20 will next be described in the context of an operation, that is, a method for controlling an amphibious vehicle. In particular, it is assumed that the vehicle is operating on land (i.e. land mode) and the engine of the vehicle is moving at a certain speed. The movement of the vehicle may be effected via a conventional steering wheel system. The sensors 24 may continuously sense for environmental data, for example temperature data via the CANbus, to adjust the speed of the first and/or second cooling fans or to turn first and/or second cooling fans on or off.

When the operator wishes to enter to a water body, e.g. a sea body, the operator actuates the swim mode switch. The HCM 22 receives the swim mode signal and sends control signals 206 to the swim isolation valves 30 to enable access to the first and second swim propellers. The joystick may then be used to control the swim propeller motors to move the swim propellers in the water body in accordance with the control signals 202, 204. When the amphibious vehicle moves from the water body to land, the operator turns off the swim mode switch. A control signal is then sent to the isolation valve 30 to disable or close the isolation valve 30 so as to disable access to the swim propellers 36, 40. The fans 34, 38 can then be activated again for cooling of the amphibious vehicle's engine.

In accordance with another aspect of the invention there is a method 500 for controlling an amphibious vehicle comprising the steps of: (a.) receiving at a single controller a plurality of inputs associated with the operating environment of the amphibious vehicle (step s502);

(b.) determining at the single controller a control signal based on the plurality of inputs (step s504);

(c.) sending the control signal from the single controller to a drive; the drive arranged to drive a fan and/or a propeller (step s506).

The amphibious vehicle may be arranged as described in earlier embodiments, where the amphibious vehicle comprises multiple drives in the form of hydraulic pumps 26, 28.

5 In some embodiments, the method further comprises the step of sending at least one control signal to enable or disable a swim isolation valve (step s508). Where the swim isolation valve is enabled, access to drive the swim propeller is permitted, and when the swim isolation valve is disabled, access to drive the swim propeller is denied. The at least one control signal to enable or disable the swim isolation valve may be sent prior to the control signal from the single controller to the drive (i.e. prior to step s506).

10 In some embodiments, the step of determining a control signal in step s504 comprises the step of receiving at least one temperature parameter of the operating environment of the amphibious vehicle, receiving a speed parameter of the engine of the amphibious vehicle, and receiving a predetermined duration of past control signal as feedback (step s510). The control signal may be in the form of an electrical voltage

15 and/or an electrical current.

Fig. 6 shows a state machine diagram of the operation of the amphibious vehicle between the land mode and the swim mode. It is to be appreciated that the fault management is incorporated as part of the safety or risk management and the fault management module will be activated when a fault is discovered during the land

20 mode, fan control, and/or swim mode and swim control. For example, if the fan control is not adjusted to an increase of the fan speed of the fan system in land mode, the fault management system will detect the error and issue a warning or corrective measures.

While the control signal(s) have been described as in the context of electrical current signal(s), it is to be appreciated that electrical voltage signals may also be

25 supplemented with or be in replacement of the electrical current signal(s).

In accordance with another aspect of the invention, there is an electronic controller for controlling an amphibious vehicle to switch the amphibious vehicle between a land mode for movement on land and a swim mode for movement on a water body. The

30 electronic controller may be arranged in signal communication with an isolation valve, the isolation valve in turn arranged to enable and disable access to a plurality of drives, wherein a first drive of the plurality of drives is associated with the land mode

and a second drive of the plurality of drives is associated with the swim mode; and wherein the electronic controller is operable to send a control signal to the isolation valve to switch between the land mode and the swim mode.

5 It is appreciable that the various elements may be described in the earlier embodiments. For example, the electronic controller can be the HCM 22, the isolation valve can be the swim isolation valve 30, the plurality of drives may include hydraulic drives 26, 28.

10 While various embodiments have been described with reference to hydraulic drives, it is to be understood other drives may be suitable for providing the drive force to the cooling fans and/or propellers.

It should be appreciated by the person skilled in the art that the above invention is not limited to the embodiments described. In particular, modifications and improvements may be made without departing from the scope of the present invention.

15 It should be further appreciated by the person skilled in the art that one or more of the above modifications or improvements, not being mutually exclusive, may be further combined to form yet further embodiments of the present invention.