

Description

Simulation system for training crew members of a military watercraft

5 The invention relates to a simulation system for simultaneously training a plurality of crew members of a military watercraft. In addition, the invention relates to a method for operating a simulation system for the simultaneous training of a plurality of crew members of a military watercraft.

10 Operating a military watercraft places high demands on the crew members operating the military watercraft. Apart from the basic know-how and skills required to operate the watercraft, it is also necessary for crew members to understand how to apply this know-how and skillset, particularly in high-stress situations. This requires that the relevant knowledge and skills are practiced under conditions that are as realistic and stress-inducing as possible. While such training can be conducted in principle on an
15 actual military watercraft, this approach also has certain disadvantages: First, military watercraft used for training purposes are unavailable for missions and this could impair the necessary readiness for deployment, particularly when there is a limited number of available military watercraft. In addition, possible training scenarios, in particular emergency situations that can be practiced on a real military watercraft, are limited.
20 Specifically, malfunctions and/or failures of system components can only be trained to a limited extent under realistic conditions on board a military watercraft without endangering the vessel itself or its crew. Finally, conducting high-stress training on an actual watercraft carries the risk that stress-related operational errors could lead to real risks and complications for the watercraft and crew members on board the
25 watercraft. For example, the risk of accidents, even including the sinking of the watercraft, cannot be ruled out in principle. Consequently, there is a need for a simulation system to train crew members of a military watercraft under the most realistic conditions possible, which can help to avoid the aforementioned disadvantages.

30 The invention is based on the object of creating a simulation system for training a plurality of crew members of a military watercraft.

The object on which the invention is based is achieved by the features of the independent patent claims. Embodiments of the invention are specified in the dependent
35 patent claims.

Embodiments comprise a simulation system for the simultaneous training of a plurality of crew members of a military watercraft. The simulation system comprises a first simulation environment with a physical control room of the watercraft for training a
40 first group of crew members.

The first simulation environment comprises one or more first physical control elements of the watercraft. The first physical control elements are each configured to set one or more control parameters for operating the watercraft. The control station is

configured to record the control parameters set by means of the first physical control elements and to communicate them to a simulation interface of the simulation system.

5 The simulation system also comprises a second simulation environment, spatially separate from the first simulation environment, for training a second group of crew members. The second simulation environment comprises technical means configured to provide a visual simulation that comprises one or more at least partially virtual copies of one or more second physical control elements of the watercraft for setting the control parameters. The technical means are also configured to record the control
10 parameters set by means of the copies and to communicate them to the simulation interface of the simulation system.

One or more of the first and second control elements may, for instance, be the same control elements paired correspondingly. For example, all first and second control
15 elements may be paired as the same control elements. For example, one or more of the first and second control elements may be different control elements that are configured to set the same control parameter for the operation of the watercraft. For example, a corresponding first control element is a control element in the control station of the watercraft for setting a control parameter from the control station, i.e. remotely,
20 such as the opening degree of a valve that can be controlled remotely from the control station and electrically actuated. By way of example, a control element in the control station, such as a console with a user interface for controlling the valve that can be electrically actuated remotely, is the corresponding first control element. For example, a corresponding second control element is a control element for locally setting the
25 same control parameter on site. By way of example, the corresponding second control element is the same valve that is additionally configured for manual operation on site in order to adjust the opening degree of the valve. For example, all first and second control elements can each be different control elements configured to set the same control parameter for the operation of the watercraft.

30 The technical means comprise, for example, display devices for visually rendering the visual simulation. These may be, for example, a screen of a desktop PC or a display of a mobile portable device. For example, they may be smart glasses for rendering a virtual reality, i.e. VR glasses. They may be, for example, an augmented reality device, i.e. a projection device, in particular wearable projection devices, for projecting
35 virtual elements into the physical reality or a digital rendering of the physical reality, e.g. a partial physical model or partial physical reproduction of the actual watercraft. For example, a corresponding physical reproduction comprises one or more tactile elements. By way of example, wearable projection devices are smart glasses for reproducing virtual elements that augment physical reality, i.e. augmented reality
40 glasses, referred to below as AR glasses. These AR glasses create a mixed reality, allowing crew members to see both the actual environment, such as tactile elements, and the superimposed virtual elements of the virtual reality. This has the advantage,

for example, of facilitating safe, accident-free movement within the second simulation environment.

5 The simulated watercraft may be, for example, a simulation of a generic military watercraft, for example a military watercraft that is generically representative of a particular type or a particular series. The simulated watercraft may be, for example, an individual military watercraft simulation, i.e. a simulation of a specific real-world watercraft. This can be advantageous when simulating the operation of a military watercraft that has been practically manufactured as a unique model. In this case, even
10 with watercraft from the same production series of an identical watercraft type, variations may occur to such an extent that the watercraft must be treated as unique items for training purposes.

15 The integration density of technical components is very high in a military watercraft, while at the same time the available space is limited. It may therefore be necessary for crew members to be familiar with the exact layout of their environment, so as to enable rapid response actions in case of an emergency. Consequently, it can be particularly important for the crew training to take place under realistic conditions. Therefore, up to now, the crew has primarily been trained on board the watercraft, although
20 this brings with it the aforementioned disadvantages. A simulation system that uses a visual simulation of parts or the entire military watercraft during training can contribute to training the crew under realistic conditions, without the need to use the actual military vessel itself for this purpose or to completely reconstruct it for training purposes.

25 The visual simulation may offer a virtual reality environment, for example, i.e. a 3D virtual environment in the form of a virtual 3D model of the military watercraft. Using a virtual reality environment has the advantage that, for realistic training of crew members on a plurality of different stations of the watercraft, i.e. in a plurality of different
30 areas of the watercraft, the actual watercraft is not needed. This means that downtime of the actual military watercraft for operations during the training period can be avoided. In addition, damage to the actual military watercraft and real dangers for crew members during training, even in hazardous situations, can be prevented.

35 Virtual reality is used, for example, to simulate as accurately as possible a military watercraft, for example a generic or individual watercraft on which the crew is to be trained. In addition, virtual reality is used, for example, to capture all actions performed by the crew and all simulation parameters, in order to simulate the real behavior that an actual watercraft would exhibit under identical conditions and convey this to the
40 crew members being trained.

The virtual reality may be constructed from CAD data of the military watercraft and/or photographs of the vessel, for example. Due to the extremely high integration density of electronic components in military watercraft, even slight deviations within the same

series of a class of watercraft may lead to identical components being arranged at different positions on the different military watercraft, where appropriate. To ensure effective training outcomes and alignment between the virtual reality and the actual military watercraft, it is important to create the most accurate representation possible of the military watercraft in virtual reality. CAD data, photos, and 3D scans can effectively provide the machine-processable resources to achieve this.

The technical means of the second simulation environment comprise, for example, a plurality of devices for generating and displaying a virtual reality or components of a virtual reality for providing the visual simulation. The corresponding devices are used, for example, as access devices for the crew members of the second group of crew members to enter the virtual reality.

In this context, a virtual reality is understood to be a three-dimensional virtual computer model that, on the one hand, represents the environment, i.e. the military watercraft. On the other hand, the virtual reality also includes the possibility of interacting with this environment, for example operating virtual copies of the second control elements. Operating the virtual copies of the second control elements includes actions such as operating mechanical switches, opening or closing valves (e.g. valves in hydraulic lines), and/or operating other mechanical devices for controlling functionalities of the military watercraft. In addition, the virtual reality includes the calculation of the effects of these interactions, potentially including external factors dictated by the scenario given in the simulation of the military watercraft's operation, such as simulated system failures, damage, and the like. As a result of these calculations, status values are provided, for example, that define an actual simulated state of the military watercraft.

This means that, in virtual reality, exactly the same environment can be provided for training crew members as would exist on the actual military watercraft if the training were conducted on the actual military watercraft rather than using the simulation system. Although there is naturally a difference between a real environment and a virtual one, the exact match pertains to the technical features of the military watercraft. For example, doors and passageways are located in the same places, as are computer consoles, switches, levers, and other control elements. This can be advantageous, since quickly locating certain devices is part of the training, allowing necessary actions to be carried out without delay, such as searching in case of an emergency. It is worth noting in this case that seemingly identical military watercraft, for example within an identical class of military watercraft, also within a series, may exhibit very substantial differences from one another. Therefore, an exact reproduction of an individual military watercraft in virtual reality can be advantageous to the training outcome.

Training during normal operation of the military watercraft may comprise, for example, standard routines for operating the military watercraft, such as regular maintenance and inspection tasks. The training may also involve scenarios deviating from normal

operation, such as the simulation of malfunctions, for example in the form of emergency situations, or threat response, such as the failure of one or more devices, water ingress, fire, or even a combat situation. In this training, participating crew members are expected to learn and practice the procedures that would then facilitate easier execution in a similar real-life situation.

For example, the virtual reality may also comprise representations of crew members participating in the training in the form of avatars. An avatar rendered in virtual reality does not need to reproduce or represent a specific person in this case, in particular it does not need to represent the appearance of the represented person. For simplicity, generic avatars may be used, for example. It is also possible to implement individualized or generic avatars with specific characteristic similarities. These corresponding characteristic similarities may, for example, be physical traits such as skin color, hair color, eye color, and facial structure, etc. To individualize avatars, 3D scans of the faces of the crew members of the watercraft could be created, for example, allowing each crew member to be assigned an individual avatar with the recreated facial features of the corresponding crew member. Given the spatial constraints on a watercraft, interaction between participating crew members can be particularly important. So that a crew member can quickly reach the location of an action, it is often necessary to pass by other crew members. To achieve a positive training outcome, a virtual simulation or representation of all crew members present in the virtual reality can be useful.

An access device for entering virtual reality is used in this case to display the sections of the military watercraft generated in virtual reality and is equipped with input means for manipulating elements within the areas of the military watercraft created in the virtual reality. For example, the virtual reality may be displayed on a screen, such as a computer console, or a portable mobile device, or corresponding smart glasses. For example, smart glasses of this kind may be VR glasses with a headset and a motion capture system and/or a controller. For example, smart glasses of this kind may be AR glasses with a headset and a motion capture system and/or a controller. Inputs for manipulating the virtual reality may be made via keyboard, mouse, joystick, controller, gesture recognition, voice recognition, or motion capture devices, for example. A corresponding access device comprises, for example, at least one display device and one input means. In addition, an access device may have an acoustic communication device, for example, including a microphone and one or more headphones, for example. A corresponding acoustic communication device allows crew members using the access devices to communicate with each other and with other crew members participating in the training in different simulation environments of the simulation system, such as the first group of crew members.

Entering the virtual reality in this case refers to the use of a corresponding access device. In the simplest case, entering the virtual reality can be achieved, for example, by putting on and activating an appropriate smart glasses device, putting on and

activating a suitable headset, picking up and activating a suitable mobile device, and/or accessing a visual display of the virtual reality on a desktop PC or corresponding computer console.

- 5 The simulation interface of the simulation system comprises a memory. Stored in the memory is a database containing definitions of one or more first physical control elements and one or more copies of one or more second control elements. The definitions for the defined first control elements and copies of the second control elements each establish a first prioritization for simulated normal operation of the watercraft, in
10 which the settings of the control parameters according to the first physical control elements are prioritized as the exclusively valid control parameter settings for the simulation of the watercraft over the settings according to the copies of the second control elements. In addition, the simulation interface of the simulation system is configured to switch from one or more first prioritizations to one or more second prioritizations in response to a simulated deviation from the normal operation of the watercraft. The one or more second prioritizations prioritize, for the simulated deviation, the settings from one or more copies of the second control elements associated with the second prioritizations over the settings from one or more first physical control elements associated with the second prioritizations as the exclusively valid settings of
15 the corresponding control parameters for the simulation of the watercraft.

Embodiments may offer the advantage of providing a simulation system for simultaneously training a plurality of crew members of a military watercraft, for example under the most realistic conditions possible. This system not only trains individual crew
25 members but also the interaction between a plurality of crew members. This plurality of crew members may, in particular, be individuals deployed in different areas of the military watercraft.

The simulation system comprises a first simulation environment for training a first
30 group of crew members and a second simulation environment for training a second group of crew members. The first simulation environment comprises a physical control room of the watercraft. The control room is a technical facility for operating the military watercraft. The control room comprises, for example, the control station, through which essential functions for the operation of the watercraft can be controlled and regulated. For example, the control station comprises a plurality of navigational
35 instruments, technical controls, and/or components. These enable the military watercraft to be maneuvered and its operation controlled, for example. In addition, the control room contains, for example, tactical systems for controlling weapons systems of the military watercraft.

40 In some embodiments, the first simulation environment can be arranged on a movably mounted platform. On the platform, for example, there is an arrangement of a plurality of hydraulic, pneumatic, and/or electrical actuators, which are controlled by a motion

control system of the platform to simulate the movements of the watercraft during the simulated operation.

Embodiments may offer the advantage that, using the movably mounted platform within the first simulation environment, movements of the watercraft can be simulated during the course of the simulated operation. The first simulation environment, such as a first simulation room, is arranged on a movably mounted platform for this purpose. A plurality of actuators are arranged on the movably mounted platform, for example. The actuators are, for example, hydraulic, pneumatic, and/or electrical actuators which are configured to adjust the tilt angle of the movably mounted platform, and therefore of the first simulation environment, in different directions. For this purpose, the actuators are controlled by a motion control system on the platform to simulate the movements of the watercraft during simulated operations. The corresponding movements of the watercraft are replicated by identical movements of the platform driven by the actuators, such as by tilting the movably mounted platform accordingly. The simulated movement of the watercraft can represent movements due to natural environmental conditions, for example, such as wave action, and/or due to the maneuvering actions of the watercraft. In the case of a submarine, corresponding maneuvering actions comprise diving and/or surfacing maneuvers, for example. The first simulation environment, such as a first simulation room, for example, can be tilted and/or inclined to reflect the simulated position of the watercraft in space, allowing the movements of the simulated watercraft to be directly reproduced and therefore felt by the crew members training in the first simulation room.

The first simulation environment comprises one or more first physical control elements of the watercraft, each configured to set a control parameter for operating the watercraft. These first physical control elements may comprise, for example, valves or switches. The first control elements in this case comprise mechanical components, for example, that allow for mechanical adjustments to the corresponding first control elements. The adjustments of the corresponding first control elements therefore result in a physical state thereof that corresponds to the adjustment. For instance, one or more of the first control elements are configured in such a manner that the mechanical components can be operated both electrically, such as by activating an electric motor, and manually. In real military watercraft this has the advantage that, on the one hand, effective central electronic control of the corresponding first control elements is enabled and, on the other hand, even in the event of an electrical malfunction, manual operation of the corresponding mechanical components is still always possible. For example, in the first simulation environment, the control room, as the first control element, comprises an operating element for operating the corresponding electrically operable component. Corresponding first physical control elements are, for example, operating elements on a console in the control room, such as a touchscreen, a trackball and/or one or more buttons, for example. A second control element may be, for example, a corresponding manually operable component.

The control room is configured to capture control parameters set by means of the first physical control elements and communicate them to a simulation interface within the simulation system. The correspondingly set control parameters allow a simulation of the watercraft operation based on the corresponding control parameters. For example, a simulation computer system which has access to the simulation interface or comprises the simulation interface can calculate a current state of the watercraft using a state simulation program, a digital model of the watercraft, and the control parameters that have been set.

- Settings of the first physical control elements in the first simulation environment are, for example, recorded or read in so that their effects on the state of the military watercraft can be simulated and displayed in the virtual reality, for example.

In addition, the simulation system comprises a second simulation environment, spatially separate from the first simulation environment, for training a second group of crew members. The second group of crew members is trained for deployment in areas of the military watercraft other than the control room. These may include, for example, an engine room, electronics room, battery room, torpedo room, galley, living quarters, and/or other sections of the watercraft. For the corresponding training, the second simulation environment comprises technical means that are configured to provide a visual simulation that comprises one or more at least partially virtual copies of second control elements for setting control parameters. The visual simulation may be a simulation, for example, that includes the control room in addition to other areas of the military watercraft. For example, the virtual simulation encompasses the entire military watercraft.

Since it is technically challenging, for example, to provide a full-scale military watercraft, such as a submarine, on a movably mounted platform for training purposes, using a first simulation environment arranged on a correspondingly movably mounted platform, along with a second simulation environment arranged independently of the first simulation environment, allows at least selected areas of the military watercraft to be supplied on a movably mounted platform that simulates movements of the military watercraft during simulated operation.

The second simulation environment is not, for example, arranged on a movably mounted platform. Alternatively, the second simulation environment can also be arranged on a second movably mounted platform, wherein a plurality of hydraulic, pneumatic, or electrical actuators is arranged on the second platform. A motion control system for the second platform can operate the actuators, in order to simulate movements of the watercraft during simulated operation.

For example, the visual simulation enables crew members in the second group to train for tasks in one or more areas of the watercraft. The corresponding visual simulation may be, for example, a fully virtual simulation, in which the crew member being

trained controls an avatar in the virtual environment of the watercraft. For example, the visual simulation is a mixture of virtual simulation and real conditions. For this purpose, the technical means comprise, for example, augmented reality devices. For example, physical components and/or physical replicas and/or physical mock-ups of components of the watercraft are arranged in the second simulation environment and are supplemented with virtual elements so that, for the crew member being trained, a complete picture is created from the combination of physically present components and virtual additions, i.e. a visual simulation, which matches the respective areas of the watercraft in which the corresponding crew member is to hone their skills.

For a military watercraft, it may be necessary for crew members undergoing training to be trained not only at one station of the watercraft, i.e. in one area of the watercraft. Particularly in cases of deviations from normal operation, such as malfunctions of the watercraft, for example in hazardous and/or emergency situations, the deployment of crew members may be required in locations outside their usual workspace. For this purpose, the crew members typically need to be able to reach several locations on the watercraft during training. In the case of training using a plurality of spatially separated simulation environments, a physical transition from one simulation environment to another during the simulation operation may prove cumbersome, challenging, or even impossible for crew members.

For example, in the case of a training scenario using a plurality of spatially separate simulation environments, in which at least one of the simulation environments is arranged on a movably mounted platform, a physical transition from one simulation environment to the other may prove difficult or impossible for crew members. This is true particularly during an active training simulation. Entering a simulation environment located on a movably mounted platform can be challenging. This is particularly true if the platform, such as a freestanding platform, is arranged at a significant distance above the ground, to ensure sufficient freedom of movement for the platform above the ground. As long as the simulation is running and if the platform movements have not yet stopped and/or are just stopping, entry may not be possible for safety reasons.

For example, one or more of the second control elements are identical to a first control element, meaning that one or more of the copies of second control elements are copies of the corresponding first control elements. If, during the simulation, a simulated deviation from normal operation occurs that makes it necessary for a crew member from the second group to operate a first control element that the first simulation environment physically includes, for example, the corresponding crew member may be prevented from reaching the corresponding first physical control element due to the spatial separation and/or the arrangement of the first simulation environment on a movably mounted platform. Instead, the corresponding crew member must rely on an at least partially virtual copy of the corresponding first control element within the second simulation environment, in order to operate the corresponding first control element.

For example, in the event of a deviation from the normal operation of the watercraft, it may become necessary for the crew members undergoing training to set a control parameter for operation of the watercraft, which is typically set remotely from the control room during normal operation, on site instead. For this purpose, a valve or a switch, for example, needs to be operated manually on site.

When a simulation system comprises both physical control elements and also at least partially virtual copies of the corresponding control elements, which are each configured to set the same control parameter for operation of the watercraft, avoiding contradictions and inconsistencies in relation to the control parameters that are set becomes a challenge.

A control element, such as a valve, which is arranged as a physical component in the first simulation environment, can only be physically operated and adjusted there, as otherwise the mechanical or physical state of the control parameter thereby set would not match the control parameter used in the training simulation. A corresponding change in the physical state of a control element can, for instance, be transferred to the virtual copy of the corresponding element in the second training environment, ensuring that the visual simulation reflects the same state for the copy of the physical control element as the physical control element has assumed as a consequence of the adjustment. If it then becomes necessary to set a control parameter by means of the at least partially virtual copy of the corresponding control element, contradictions may arise between the physical setting of the physical control element and the virtual settings of its copy, potentially causing complications in simulating the state of the watercraft. If the setting of the at least partially virtual copy of a physical control element is changed, this change does not transfer to the physical state of the physical control element. Hence, the physical state of the physical control element contradicts the setting made by means of the copy. For instance, in the case of a valve, the virtual copy of the valve might be closed while the physical valve remains open, or vice versa. In the case of a switch, the virtual copy of a switch can be toggled, for example, while the physical switch remains unchanged.

In the simulation system, a simulation interface is provided which comprises a memory containing a database. This database holds definitions of all control elements, assigning operational prioritizations to each of the corresponding control elements, e.g. a first prioritization and/or a second prioritization. The corresponding first prioritization, for example, specifies that, for the simulated normal operation of the watercraft, the settings of the control parameters made through the first physical control elements are prioritized over the settings made according to copies of the second control elements. Consequently, under the first prioritization, the settings of the control elements according to the first physical control elements are the only valid settings for simulating the watercraft.

A corresponding first prioritization can be implemented, for example, by granting write access only to the first simulation environment or the control room for recorded settings in the simulated normal operation, while the second simulation environment does not have write access to the control parameters through the virtual copies of the second control elements. For instance, in the simulated normal operation of the watercraft, the second simulation environment only has read access to read the control parameters set by the first physical control elements. Based on this read access, the second simulation environment, or the technical means of the second simulation environment, can read the currently valid control parameters set by means of the first physical control elements and, if necessary, adjust the state of virtual copies of the second control elements, which are configured to control the same parameters, accordingly. For example, the states of the copies of the second control elements mimic the states of the first physical control elements. This adjustment of the state of virtual copies of the second control elements can also be done centrally.

In addition, the simulation interface is configured to switch from first to second prioritizations in response to a simulated deviation from the normal operation of the watercraft. The second prioritization specifies for the simulated deviation from normal operation that the settings of control parameters made according to the virtual copies of the second control elements are prioritized as the only valid control parameter settings for simulation of the watercraft. In the event of a corresponding deviation from normal operation, the simulation of the state of the watercraft is therefore no longer based on the control parameters set by means of the first physical control elements, but rather based on the control parameters set by means of the virtual copies of the second control elements.

A switch from one or more first prioritizations to corresponding second prioritizations may, for example, be triggered by the simulation of the state of the watercraft, representing a deviation from normal operation, for example, which requires a setting of one or more control parameters by means of the copies of the second control elements. These second control elements may, for example, be control elements for the local on-site setting of control parameters, such as the opening degree of a valve that must be manually operated on site. For example, this valve is a corresponding second control element. The first control elements may be control elements of the control room of the watercraft, for example, used to set control parameters from the control room, i.e. remotely, such as the opening degree of a valve that can be operated electrically from a distance via the control room. For example, a control element in the control room, such as a console with a user interface for operating the valve that can be controlled electrically from a distance, constitutes a corresponding first control element. A switch from one or more first prioritizations to corresponding second prioritizations can, for example, be triggered by an action and/or the failure of one or more crew members. A switch from one or more first prioritizations to corresponding second prioritizations can be triggered, for example, by an external action, such as by a trainer

who manages the simulation and is not one of the crew members. A trainer of this kind may monitor the training from a control room, for example, and if necessary initiate a deviation from the normal operation of the watercraft, i.e. a switch from the first prioritization to the second prioritization. The corresponding prioritization ensures that contradictions between the settings of the first physical control elements and the virtual copies of the corresponding second control elements can be avoided.

For those control elements subject to both normal operation and second prioritization, it is clearly defined which control elements or which embodiments of the corresponding control elements, i.e. the first physical control element or the at least partially virtual copies of the second control element, are valid for the settings of the control parameters, and therefore for the simulation of the operation of the watercraft. For example, second prioritization can be implemented by reassigning read and write permissions for the control parameters in the event of a deviation from normal operation. As part of this reassignment, write permissions may be exclusively assigned to the virtual copies of the corresponding second control elements, for example, while no write permissions are available for the first physical control elements.

For example, the database of the simulation interface may comprise definitions of both the first prioritizations and also the second prioritizations. Switching between first prioritization and second prioritization can be controlled by means of a flag, for example. If a corresponding flag is set, for example, a switch from first to second prioritizations occurs. If the flag is deleted, first prioritization applies once again. In this case, different prioritizations may exist for different control parameters or control elements. Not all flags need be identical for all control parameters or control elements. For example, first prioritizations may apply to some of the control parameters or control elements, while second prioritizations apply to others. It is also possible for the flags to be set uniformly for all control parameters or control elements, meaning that either first prioritizations apply to all control parameters or control elements, or that second prioritizations apply to all control parameters or control elements.

A corresponding scenario involving a deviation from normal operation, such as a malfunction scenario of the watercraft, might look like this, for example: A malfunction could involve the release of smoke from a fire, for example, causing the first group of crew members in the first simulation environment to become incapacitated. During the simulated operation of the watercraft, these crew members may no longer be able to perform any further actions, for example. In this case, crew members from the second group of crew members in the second simulation environment would need to set second control elements, for example, which would actually have to be set by members of the first group of crew members, located physically in the first simulation environment. Since a physical transition from the second simulation environment to the first simulation environment might be difficult or impossible, members of the second group of crew members can virtually access the area of the watercraft physically represented by the first simulation environment by means of the visual simulation. In this

virtual setting, members of the second group of crew members can operate the virtual copies of the second control elements, for example, and set the corresponding control parameters. Given that second prioritizations apply in the case of a deviation from normal operation, the control parameters set accordingly are now used to calculate the state of the watercraft during the simulated deviation from normal operation, instead of the settings of the first physical control elements. This enables a realistic simulation, even if the first group of crew members is incapacitated and further adjustment of control parameters by means of the first physical control elements in the first simulation environment is no longer possible.

A scenario of a deviation from normal operation can generally also be any scenario in which it becomes necessary to adjust a control parameter normally set by means of the control room of the watercraft or a first control element included in the control room on-site using a second control element. This may be necessary, for instance, if remote control from the control station fails, or if one or more crew members at the control room become incapacitated.

By using prioritizations, such as the first and second prioritizations described here, it is possible to prevent, for example, settings of control parameters in the real first simulation environment made through first physical control elements and settings in the virtual environment made through at least partially virtual copies of second physical control elements from leading to inconsistencies or even mutual blocking during the simulation of the operation of the military watercraft. This risk of inconsistency arises especially with mechanical settings in which the mechanical components of the respective control elements are operated. For example, a mechanical valve which is arranged in physical form in the first simulation environment can only be physically actuated there as long as the first simulation environment is actively participating in the simulation of the operation of the military watercraft. Otherwise, there would be a risk that the mechanical state of the physical valve in the first simulation environment would not correspond to the state assumed for carrying out the simulation.

If, for example, the simulation of the operation of the military watercraft were based on a setting of a virtual copy of a valve, for example, the virtual mechanical state of which does not correspond to the physical mechanical valve in the first simulation environment, this could lead to problems during the simulation of the operation. For instance, if the physical valve is closed but the virtual copy is open, and the simulation requires the crew members of the first group in the first simulation environment to close the physical valve, they will not be able to do so. Conversely, if the physical valve is open but the virtual copy is closed, and if the simulation requires the crew members of the first group in the first simulation environment to open the physical valve, they would also be unable to do so. Problems of this kind can be avoided by means of the prioritizations described here.

For example, a change in the setting of the first physical control element in the first simulation environment can be displayed in the second simulation environment by a corresponding adjustment in the state of virtual components in the copy of the corresponding first physical control element, also in the second simulation environment.

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For purely electronic settings of control parameters, such as information displayed on IT systems, inconsistencies can be avoided, for example, since the corresponding settings can be adjusted in both simulation environments without discrepancies between the physical states of mechanical components and the states on which the simulation is based in the first simulation environment.

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Feedback from a state simulation program, i.e. state values of the military watercraft calculated or simulated using the set control parameters, can be displayed in both simulation environments. For example, a value for a fuel level of a tank of the military watercraft can be calculated based on a previous tank fill level and control parameters set by the crew members. The resulting state value for the tank fuel level can then be written to a shared memory which is provided by the simulation interface, for example, and read and displayed by both simulation environments. For instance, the control room can read the corresponding state value from the shared memory and display it on a display device. For example, the technical means of the second simulation environment can read and display the corresponding state value from the shared memory.

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In the event that all crew members in the first group in the first simulation environment are incapacitated due to a deviation from normal operation, such as the presence of smoke from a fire, a switch from the first prioritization to the second prioritization may occur. Following this switch, control parameters in the first simulation environment can now be virtually adjusted using the at least partially virtual copies of the second control elements of the first simulation environment and used as the basis for simulating the operation of the military watercraft. This option, for example, is blocked in the case of first prioritization. For example, the adjustment of control parameters using the first physical control elements in the first simulation environment is blocked, meaning that the first simulation environment is, for example, disconnected from the simulation of the military watercraft's operation. In this case, the settings or switch states in the first simulation environment become irrelevant. For example, the rights to adjust control parameters are transferred from the first simulation environment to the second simulation environment, thereby transferring control from the physical realm to the virtual realm.

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Deviations from the normal operation of the military watercraft comprise, for example, malfunctions of the watercraft. For example, malfunctions may involve a fire, such as in the galley of the watercraft, failures in the IT system or electronic components of the watercraft, or flooding in a specific area of the watercraft. A deviation from normal operation, such as in the event of a malfunction, may represent a training task to be

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completed, for example, which is triggered by a simulation prompt from a trainer. A malfunction could also arise from the simulation of the watercraft's operation, for example, perhaps due to an operational error or the negative effects of an event in a simulation scenario, such as an attack on the military watercraft.

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The simulation interface, for example, comprises a list of predefined deviations from normal operation, such as in the form of predefined malfunctions by the watercraft, for which a switch from first prioritizations to second prioritizations occurs for one or more of the first control elements associated with the corresponding second prioritizations and one or more copies of second control elements associated with the corresponding second prioritizations. For example, for each predefined deviation from normal operation, one or more first prioritizations are defined, so that if the corresponding deviation occurs, a switch to second prioritizations assigned to the corresponding deviation occurs. If one of these deviations from normal operation occurs during the simulation of the watercraft operation, then for this deviation the switch from first prioritizations to second prioritizations takes place, i.e. a predefined switch from first prioritizations to second prioritizations associated with the corresponding deviation.

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20 According to embodiments, the memory of the simulation interface also stores the currently valid control parameters for the simulation of the watercraft.

Embodiments may have the advantage that the simulation interface provides the control parameters valid for the simulation of the watercraft. The corresponding control parameters can then be read out and used in the first and second simulation environments for the simulated operation of the watercraft. In addition, or alternatively, the corresponding control parameters can be used to simulate the state of the watercraft, for example through a state simulation program. The state values resulting from this can be used to define the state of the watercraft and therefore the simulation of the watercraft in the first and second simulation environments.

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According to embodiments, the first prioritizations and second prioritizations each define write permissions.

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According to embodiments, the first prioritizations each specify that the control room in the first simulation environment has write permissions for writing the control parameters set by means of the first physical control elements, which are valid in the simulated normal operation of the watercraft, while the technical means of the second simulation environment do not have write permissions for writing the control parameters currently valid for the simulation of the watercraft. The second prioritizations specify that the technical means of the second simulation environment have write permissions to write the control parameters that are set by means of the copies of the second control elements associated with the second prioritizations and are valid in the simulated deviation from the normal operation of the watercraft, while the control room

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does not have write permissions to write the control parameters set by means of the first physical control elements associated with the second prioritizations as control parameters currently valid for the simulation of the watercraft.

- 5 Embodiments may have the advantage that the first and second prioritizations can each be implemented through definitions of write permissions. In the case of the first prioritizations, for example, it is specified in each case that the control room in the first simulation environment has write permissions for writing control parameters. In this case, the corresponding control parameters that are written are the control parameters set by means of the first physical control elements. Hence, during normal operation, the control parameters set by the first physical control elements are the control parameters valid for the simulated normal operation of the watercraft, as only these are stored as valid in the simulation interface. If there is a deviation from normal operation, the second prioritizations can specify that the technical means of the second simulation environment have write permissions. In this case, the control parameters set by means of the virtual copies of the second control elements are written to the simulation interface and are therefore valid for the simulated deviation from normal operation of the watercraft. A switch between the first prioritization and the second prioritization, i.e. a reassignment of write permissions, can be achieved, for example, by overwriting the corresponding assignments of write permissions. Alternatively, the first and second prioritizations may each define the corresponding write permissions, wherein a switch between first and second prioritizations can be implemented by setting one or more flags, for example. The corresponding flags are stored in the simulation interface of the database, for example, with the definitions of the control elements, as well as the first and/or second prioritizations.

- 30 According to embodiments, the control room in the first simulation environment has write permissions for writing control parameters set by means of the first physical control elements, just as the technical means of the second simulation environment also have write permissions for writing the control parameters set by means of the copies of the second control elements.

- 35 The first prioritizations each specify that the control parameters set by means of the first physical control elements and written by the control room are read as valid control parameters in the simulated normal operation of the watercraft, while the control parameters set by means of the copies of the second control elements and written by the technical means of the second simulation environment are not read.

- 40 The second prioritizations each specify that the control parameters set by means of the copies of the second control elements associated with the second prioritizations and written by the technical means of the second simulation environment are read as valid control parameters for the simulated deviation from normal operation of the watercraft, while the control parameters set by means of the first physical control

elements associated with the second prioritizations and written by the control room are not read.

Embodiments may have the advantage that control parameter settings are always written, regardless of whether the setting is made by means of one of the first physical control elements or by means of at least a partially virtual copy of one of the second control elements. The corresponding information is always present. It is only the prioritization that determines which of the set or written control parameters are used as valid control parameters for the simulation of the watercraft.

In this case, for example, both control parameters set by means of the first physical control elements, i.e. first control parameters, and control parameters set by means of the copies of the second control elements, i.e. second control parameters, are used. For example, each simulation environment is assigned interface parameters, into which the corresponding simulation environments are allowed to write according to the interface definition. These interface parameters can be written to by the simulation environments at any time with the control parameters set within them. A flag, which distinguishes between first prioritization, e.g. remote control, and second prioritization, e.g. local control, signals to the simulation model which of the interface values should be adopted as the valid control parameter for the simulation of the watercraft. If, for example, the flag is set to normal operation and the second simulation environment writes an opening degree of a virtual copy of a valve in the virtual environment to the simulation interface, this control parameter is present as a value in the simulation interface or in one of the interface parameters assigned to the second simulation environment but is not adopted or used as a valid control parameter for the simulation.

According to embodiments, the first prioritizations specify that the capture of control parameters set by means of the first physical control elements by the control room in the first simulation environment is enabled, while the capture of control parameters set by means of the copies of the second control elements by the technical means of the second simulation environment is disabled. The second prioritizations specify that the capture of control parameters set by means of the copies of the second control elements is enabled by the technical means of the second simulation environment, while the capture of control parameters set by means of the first physical control elements by the control room in the first simulation environment is disabled.

Embodiments may have the advantage that switching between first and second prioritizations can be implemented, for example, by enabling and disabling the relevant sensors for detecting settings of the first and second control elements, respectively. For example, the first prioritization may define that capturing the control parameters set by means of the first physical control elements by the control room is enabled, while capturing the control parameters set by means of the virtual copies of the second control elements by the technical means of the second simulation environment is

disabled. In this case, for example, the simulation interface can indicate to the control room in the first simulation environment or the technical means of the second simulation environment whether normal operation or a deviation from normal operation of the simulation is occurring. In the case of normal operation, the detection of settings for the first physical control elements is enabled, while a corresponding detection of the virtual copies of the second control elements is disabled. If a deviation from normal operation occurs during the watercraft simulation that requires switching from first to second prioritizations, capturing the virtual copies of the second control elements is activated, for example, while capturing the first physical control elements is, in turn, disabled, for example. For example, the simulation interface indicates that a switch from normal operation to a deviation from normal operation has occurred, whereupon the control room in the first simulation environment disables detection of the setting of the first physical control elements, while the technical means of the second simulation environment enable detection of the virtual copies of the second control elements.

According to embodiments, the copies of the second control elements are each a complete virtual 3D model of the respective second control element. The technical means in the second simulation environment for providing copies of the second control elements comprise one or more output devices with one or more displays for visual output of the virtual 3D models, as well as one or more input means for the virtual simulation of operating the virtual 3D models.

Embodiments may have the advantage of using fully virtual 3D models as the virtual copies of the second control elements. In this case, the settings for the corresponding virtual copies of the second control elements take place exclusively in the virtual space using technical means. The technical means may comprise a desktop PC with corresponding input and output devices, for example. A user at the corresponding desktop PC may, for example, control an avatar in the simulation by means of input means such as a keyboard, joystick, and/or controller, which operates the complete virtual environment of the corresponding control element. The virtual environment, in particular the complete virtual 3D model of the corresponding control element, is displayed to the corresponding crew member on a screen of the desktop PC, for example. In addition, the technical means may comprise a tablet or other mobile portable device with both input and output means, for example. By means of the corresponding input and output means of the mobile portable device, such as in the form of a touchscreen, a crew member can control an avatar in the virtual environment to operate the first physical control element. For example, the technical means comprise smart glasses, such as VR glasses, which act as an output device allowing a crew member to view the virtual simulation with the complete virtual 3D model of the corresponding control element. A crew member using the smart glasses can control an avatar within the virtual simulation through gestures and/or additional controllers. The corresponding gestures may be captured by means of digital cameras and interpreted as inputs.

According to embodiments, the technical means in the second simulation environment for providing copies of the second control elements comprise one or more tactile elements to physically reproduce the haptic characteristics of one or more second control elements. The technical means also comprise one or more augmented reality devices which are configured to provide complementary components of the corresponding second control elements in virtual form to the tactile elements. The one or more augmented reality devices each comprise one or more displays for visual output of the complementary virtual components of the copies of the second control elements and one or more sensors to capture interactions by the crew members of the second group of crew members using the one or more augmented reality devices with the tactile elements and/or the complementary virtual components when operating the copies of the second control elements.

Embodiments may offer the advantage that the virtual copy of the second control element is not a purely virtual copy. Instead, a tactile element is provided which has the advantage that physical haptic characteristics of the corresponding second control element can be reproduced. Consequently, a crew member intending to operate the partially virtual copy of the second control element can be trained not only for the correct theoretical operation of the second control element, but also for a corresponding operation in terms of haptic properties.

A tactile element of this kind enables hands-on training with the corresponding second control element. For example, the tactile element can be rotated, flipped, and/or comprises two parts that need to be screwed together or separated. This involves hands-on training with the tactile element to practice specific hand movements efficiently and effectively through practical application.

A tactile element may, for example, be a mechanical device that simulates a mechanical component of a second physical control element, for example a lever, a switch, a handwheel, or the like. In the second simulation environment, this tactile element has no functionality, for example. Operating the tactile element in the physical reality of the second simulation environment does not result in any input, for example. However, using the tactile element results in an input within the virtual reality, for example. Military watercraft routinely have devices for the manual operation of mechanical components of the watercraft, such as handwheels, for example. A handwheel of this kind can be used as a tactile element, for example, and, in virtual reality, leads to the behavior of the watercraft being simulated according to the setting of the handwheel. At the same time, using a real mechanical handwheel allows the crew member being trained to have a haptic experience during training, develop an understanding of the required force, and, potentially, optimize their manual skills for completing the task quickly. It may be advantageous for the tactile element, for example, a handwheel, to have a comparable shape, feel, and/or resistance to the real second control element on the actual watercraft. In this case, exactness is not crucial; instead, what matters

is that the crew member develops an intuitive sense of how the corresponding second control element feels and how it is operated, such as the amount of force required for operation.

- 5 This may be particularly relevant for training in stressful situations, where it is not only important to know how to operate a corresponding second control element, but also to practice the actual physical operation. The corresponding physical action should be committed to muscle memory by the crew member so that, in the event of an actual deviation from the normal operation of the watercraft, such as during a malfunction of
10 the watercraft, during extreme stress the stored motor skills can simply be recalled, allowing the correct actions to be performed intuitively without conscious thought.

- A corresponding tactile element can be integrated into the simulation using augmented reality (AR) devices. The corresponding augmented reality devices may, for
15 example, be provided by the technical means of the second simulation environment. These devices may be configured to complement the tactile elements with additional components in virtual form. For example, the background and/or environment of the corresponding second control element can be virtually augmented, so that the corresponding crew member is trained in quickly identifying the second control element to be operated within a complex technical environment with a plurality of technical components. The actual operation of the corresponding second control element can then also be physically practiced using the tactile element. In addition, the complementary components can, for example, display hints and/or visually supplement components of the second control element to be operated that are not part of the tactile element.
20 The supplementary virtual components can be provided on the displays of the augmented reality devices and overlaid with the tactile element. For example, augmented reality devices comprise smart glasses with a semi-transparent display through which complementary components are shown in virtual form. These complementary virtual components can visually overlay and/or supplement the tactile element visible
25 through the semi-transparent display.
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- In this case, augmented reality refers to a computer-supported augmentation of the perception of reality. The augmentation of the perception of reality can fundamentally address all human sensory modalities. In the present case, however, it primarily targets visual perception, for example by providing a visual representation of information,
35 such as augmenting the perception of real objects or images or videos of those objects with computer-generated virtual additional information and/or virtual objects by means of superposition/overlaying.

- 40 For example, the augmentation of the perception of reality involves enhancing the perception of the physical reality/environment naturally in the analog world without electronic signal processing. For example, sensory perceptions such as images are shown through classic aids such as magnifying optics or a mirror. Virtual information such as images/objects can be overlaid in different ways, such as through an optical

projection onto a transparent screen, through which the corresponding natural physical objects can also be viewed. Virtual information is displayed, for example, by means of an electro-optical display integrated into a viewing surface, such as the lens of smart glasses, with transparent areas and additional, virtually overlaid information and/or image elements. This can be achieved with a liquid crystal display, which is largely transparent in its default state and displays virtual elements in activated areas.

For example, augmenting the perception of reality relates to an augmentation of the perception of the physical reality/environment that is subject to photoelectric conversion of an electronic signal processing before being perceived through artificial reproduction. In this case, a combination/overlay of the reproduction of sensory perceptions with virtual elements is carried out exclusively electronically. For this purpose, sensor data, for example from a digital camera, are processed by means of signal processing by software-controlled processors and then combined and reproduced via an output converter, such as a display device/screen.

An augmented reality device is therefore a device that is configured to provide and/or overlay objects in the real world with information and/or projections of digital objects in real-time, while the corresponding real-world objects are perceived by a user of the augmented reality device. In this way, the user's perception of real-world objects is augmented with information and/or projections of digital objects. In this way, an augmented reality device can be configured to implement and/or use the following: a combination of real-world objects with virtual information and/or virtual objects, real-time interaction in the form of a real-time adaptation of information and/or digital objects to changes in the real-world objects, and/or to changes in the perception of real-world objects, 3D registration of virtual objects with real-world objects. The virtual information and/or virtual objects that overlay the real objects can be constructive, for example by being added to the real objects, or destructive, for example by at least partially obscuring the real objects. The virtual information and/or virtual objects can be seamlessly interwoven with the perception of real-world objects, i.e. the physical objects of the physical world, so that the user perceives them as an immersive aspect of the real world. In this way, an augmented reality device can alter the user's ongoing perception of a real environment. The user's real environment is not completely replaced by a simulated digital environment, as is the case with virtual reality. Instead, the real environment, i.e. the user's perception of the real environment, is enriched with virtual information and/or virtual objects.

An augmented reality device makes it possible, for example, for components from the virtual world to be overlaid onto the user's perception of the real world. This may comprise the integration of immersive sensory impressions that are perceived by the user as natural parts of the observed environment. Augmented reality technology can, for instance, be used to enhance the user's perception of their physical environment with virtual information and/or virtual objects, providing an improved perception experience. With the help of augmented reality technologies, information about the user's

real environment can be interactively and virtually manipulated. Virtual information about the surroundings and their objects can be overlaid onto the real world. Augmentation processes can be carried out in real time and in semantic association with physical objects in the environment.

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An augmented reality device may comprise, for instance, a head-mounted display, smart glasses, a head-up display, a contact lens, a virtual retinal display, an eye-tap, or similar devices. A head-mounted display (HMD) is a display device worn on the forehead, for example by means of a strap or helmet. An HMD is configured in such a manner that it displays images of the physical world as well as virtual information and/or virtual objects in the user's field of view. For instance, the HMD can use sensors to monitor six degrees of freedom, allowing the system to align virtual information with the physical world and set it according to the user's head movements.

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An augmented reality device may, for example, be in the form of smart glasses, wherein an augmented reality display is shown on the glasses. This augmented reality device may use one or more digital cameras to capture the user's real-world view and then present an augmented view through an eyepiece. For instance, the augmented reality device may project augmented reality images onto a lens of the glasses or reflect them from the surface of the lens.

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As an example, and in particular, smart glasses are used as an augmented reality device, providing a direct view of the surroundings while additionally overlaying virtual elements into the environment. For instance, virtual parts of the second control elements are then projected into the real environment of the second simulation environment via the smart glasses. In addition, the environment of the military watercraft, in which the corresponding second control element is located, is projected into the real environment of the second simulation environment. Avatars of other crew members participating in the training may also be projected into the real environment of the second simulation environment. For example, a semi-transparent mirror integrated into the glasses allows the user to see both the surroundings and a display that presents the additional elements of virtual reality. Alternatively, the smart glasses may also include a digital camera that captures the environment, integrates these additional elements of virtual reality into the captured images, and presents the composite image to the crew member using the smart glasses.

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An augmented reality device may comprise, for example, a head-up display (HUD). A HUD is a transparent display that shows data without requiring the user to shift their gaze from their usual viewpoint.

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An augmented reality device may, for example, comprise a contact lens that displays augmented reality images. A bionic contact lens of this kind may comprise a display element embedded in the lens with integrated circuits, LEDs, and an antenna for wireless communication.

An augmented reality device may, for example, comprise a virtual retinal display (VRD). The augmented reality device may be configured in such a manner that it scans an image directly onto the retina of the user's eye.

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An augmented reality device can, for example, also be a monocle-like, head-mounted display worn over one eye, combining the functions of a digital camera and a display. Light rays that would otherwise pass through the center of the lens in the user's eye can be captured and replaced with synthetic, computer-controlled light for each real light ray.

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In some embodiments, the one or more first control elements comprise one or more valves, switches, and/or touch-sensitive elements of the watercraft. According to some embodiments, the one or more second control elements comprise one or more valves, switches, and/or touch-sensitive elements of the watercraft.

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In some embodiments, the one or more first control elements each comprise a mechanically operable component. In other embodiments, each of the one or more second control elements comprises a mechanically operable component.

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For example, a first and/or second control element can be a valve or a switch with an electric drive that can be operated via an automation system through the control room in the first simulation environment and/or through a virtual simulation of the control room in the second simulation environment. As a fallback option in the event of a failure or malfunction of the electric drive, the valve or switch comprises a device for manual operation. For instance, the valve has a handwheel that connects directly to the valve's gearbox, allowing the valve to be operated manually. For example, the switch can be manually flipped. The corresponding first and/or second control element may comprise a lever, for example, that can be manually operated.

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In some embodiments, the first simulation environment comprises a physical operations center of the watercraft. In other embodiments, the first simulation environment comprises a physical bridge of the watercraft.

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In some configurations, the simulation interface is provided by a simulation computer system that comprises a memory with executable program instructions of a state simulation program for simulating a state of the watercraft and a digital model of the watercraft, as well as a processor. Execution of the program instructions by the processor causes the simulation computer system to simulate a current state of the watercraft using the digital model of the watercraft and the control parameters valid for the watercraft simulation.

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Certain embodiments may have the advantage that the current state of the watercraft can be simulated or calculated using the simulation computer system. For this

purpose, the simulation computer system uses a simulation program. The simulation program employs a digital model of the watercraft. This digital model of the watercraft describes the watercraft and defines the state parameters of the watercraft and their dependencies. The state simulation program, for example, accesses the valid control parameters of the watercraft and calculates the currently valid state values for the state parameters of the watercraft based on these control parameters. The resulting state values are made available to the first simulation environment or control room and the second simulation environment or the technical means of the second simulation environment, so that they can display the currently simulated state of the watercraft to the first and second group of crew members.

Furthermore, a motion control of a movably mounted platform, on which the first simulation environment may be arranged, also takes place based on calculated state values of the watercraft, e.g. tilt angles of the watercraft.

For example, the digital model of the watercraft comprises a hydrodynamic model for calculating the movement of the watercraft. Commands from the control room for steering the watercraft are sent to the simulation computer system. The state simulation program, using the hydrodynamic model, calculates, for example, a speed as the state value of the watercraft. This speed can then be used, for example, to determine the position of the watercraft. For example, this speed can be read by a tactics simulation program and used to calculate the position of the watercraft in a tactical scenario.

In the case of a simulated weapon launch from an onboard weapon carrying ammunition, the weight of which has a significant impact on the total weight of the watercraft, such as a torpedo in the case of a submarine, a reduction in the weight of the watercraft can be calculated as an updated state value. A reduction in weight can, for example, affect the draft or diving depth of the watercraft.

In some embodiments, a switch from the simulated normal operation of the watercraft to the simulated deviation from normal operation of the watercraft occurs when an external command to switch is received via the simulation interface.

Embodiments may have the advantage that a switch from the simulated normal operation of the watercraft to the simulated deviation from normal operation of the watercraft can be initiated by an external switch command. This external switch command can, for example, be made by a crew member involved in the simulation, such as the captain of the watercraft, through an appropriate input. For instance, the external switch command is entered by a trainer who manages the simulation and is not one of the crew members. This enables an individual switch from normal operation to a deviation from normal operation, such as a malfunction, to be made at any time, allowing the crew members participating in the training to improve their rapid response skills.

For example, the simulation system comprises a command center with input means to control the simulation process in the first and second simulation environments. For example, the input means are designed to intervene in the simulation of the watercraft operation. Through the input means, it is possible to simulate the failure of individual stations, water ingress, or a fire outbreak, for example. In this way, unusual operational states, i.e. deviations from normal operation, especially malfunctions, can be easily represented. A trainer who manages the simulation and is not one of the crew members can therefore monitor the training from the command center, for example, and initiate a malfunction and/or a switch from the first prioritization to the second prioritization, as needed. For example, the trainer enters an appropriate command to this end using the input means to control the simulation process.

In some embodiments, a switch from the simulated normal operation of the watercraft to the simulated deviation from normal operation of the water craft occurs automatically via the simulation interface as part of the execution of the state simulation program, if the simulated state of the watercraft involves deviation from normal operation.

Some embodiments may have the advantage that the switch from simulated normal operation of the watercraft to a simulated deviation from normal operation can result from the simulated condition of the watercraft. If the state of the watercraft simulated by means of the state simulation program comprises a corresponding deviation from normal operation, an appropriate switch command can be issued to the simulation interface by the computer system.

In some embodiments, the simulated deviation from normal operation involves a failure of the first group of crew members. Embodiments may have the advantage that the simulation system allows for training in the full or partial failure of the first group of crew members. A failure of this kind by the first group of crew members may result, for example, from the fact that the corresponding crew members are physically no longer able to perform their duties and/or have had to evacuate the area of the watercraft represented by the first simulation environment according to the simulation. Such scenarios may occur, for example, in the event of a fire.

In some embodiments, the military watercraft may be one of the following watercraft: a submarine, an aircraft carrier, a helicopter carrier, a cruiser, a destroyer, a frigate, a corvette, a landing ship, a minelayer, a mine-clearing vessel, a minehunter, a patrol boat, a fast attack craft, or a reconnaissance ship.

Further embodiments comprise a computer-based method for operating a simulation system for simultaneously training a plurality of crew members of a military watercraft. The simulation system comprises a first simulation environment with a physical control room of the watercraft for training a first group of crew members.

The first simulation environment comprises one or more first physical control elements of the watercraft. Each of these first physical control elements is configured to set one or more control parameters for the operation of the watercraft. The control room is configured to detect control parameters set by means of the first physical control elements and to communicate them to a simulation interface of the simulation system.

The simulation system also comprises a second simulation environment, spatially separate from the first simulation environment, for training a second group of crew members. This second simulation environment comprises technical means which are configured to provide a visual simulation that comprises one or more at least partially virtual copies of one or more second physical control elements of the watercraft for setting control parameters. The technical means are also configured to capture the control parameters set by means of the copies and communicate them to the simulation interface of the simulation system.

The simulation interface of the simulation system comprises a memory. This memory holds a database containing definitions of the one or more first control elements and of the one or more copies of the one or more second control elements. The definitions for the defined first control elements and copies of the second control elements each establish a first prioritization for a simulated normal operation of the watercraft, in which the settings of control parameters according to the first physical control elements are prioritized as the only valid settings for the simulation of the watercraft, over those settings made according to the copies of the second control elements.

The method involves switching from one or more of the first prioritizations to one or more second prioritizations in response to a simulated deviation from the normal operation of the watercraft. The one or more second prioritizations prioritize, for the simulated deviation from normal operation, the settings of one or more control parameters according to one or more copies of the second control elements associated with the second prioritizations over the settings according to one or more first physical control elements associated with the second prioritizations as the only valid settings of the corresponding control parameters for the simulation of the watercraft.

Embodiments of the method may be configured, for example, for operating any of the above exemplary embodiments of the simulation system for simultaneously training a plurality of crew members of a military watercraft.

Further embodiments of the invention are explained in greater detail below with reference to the drawings. In the drawings:

Figure 1 shows a schematic block diagram of an exemplary simulation system,

Figure 2 shows a schematic diagram of a first exemplary simulation environment,

- Figure 3 shows a schematic diagram of a second exemplary simulation environment,
- Figure 4 shows exemplary embodiments of control elements,
- Figure 5 shows a schematic block diagram of an exemplary control room,
- Figure 6 shows a schematic block diagram of an exemplary technical means,
- Figure 7 shows a schematic block diagram of an exemplary simulation computer system,
- Figure 8 shows a schematic flowchart of an exemplary deviation from normal operation,
- Figure 9 shows a schematic flowchart of an exemplary deviation from normal operation,
- Figure 10 shows a schematic flowchart of an exemplary deviation from normal operation,
- Figure 11 shows a schematic flowchart of an exemplary method for simulating the state of a watercraft,
- Figure 12 shows a schematic block diagram of an exemplary simulation system,
- Figure 13 shows a representation of an exemplary simulation system,
- Figure 14 shows a representation of a first exemplary simulation environment,
- Figure 15 shows a representation of exemplary consoles of a control room.

Elements of the following embodiments that correspond to one another are marked with the same reference signs.

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Figure 1 shows an exemplary simulation system 100. The exemplary simulation system 100 comprises a first simulation environment 110 and a second simulation environment 130. In addition, the simulation system 100 comprises a simulation computer system 150 that provides a simulation interface 152. The different components of the simulation computer system 100, i.e. the first simulation environment 110, the second simulation environment 130, and the simulation computer system 150, are communicatively interconnected by means of communication links over a communication network 170. The first simulation environment 110 comprises a control room 112, which, for example, provides first physical control elements 114, such as control elements of

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the control room 112. The first simulation environment 110 may also comprise first physical control elements 114, for example, that are not part of the control room 112. The first simulation environment 110 is arranged, for example, on a movable platform 116. Actuators 118 are arranged on the platform 116. These actuators 118 may, for example, be hydraulic, pneumatic, and/or electrical actuators. A motion control 111 of the platform 116 controls the actuators 118 to reproduce the motion of the watercraft during simulated operations. The motion control 111 is arranged on the platform 116. For example, the motion control 111 may also be arranged away from the platform 116. For example, the simulation computer system 150 may comprise the motion control 111.

The second simulation environment 130 comprises technical means 132 that are configured to provide a visual simulation with at least partially virtual copies 134 of second physical control elements. These technical means 132 may, for example, comprise one or more desktop PCs, mobile portable devices such as tablets, or smart glasses. One or more of the corresponding second physical control elements may be identical to one or more of the first control elements 114 of the first simulation environment 110, for example. One or more of the corresponding second physical control elements may differ from one or more first control elements 114 of the first simulation environment 110, for example, but are each configured to set the same control parameter.

The simulation interface 152 provided by the simulation computer system 150 comprises a database 154, for example, with definitions $S_1, S_2, \dots S_N$ of the first control elements 114 and the at least partially virtual copies 134 of the second control elements. For example, for each of the control elements 114 and/or each copy 134 of a control element, the database 154 comprises a currently valid control parameter 155, i.e. $P_1, P_2, \dots P_N$. For example, these control parameters 155 stored in the database 154 are in each case the currently valid control parameters set by means of control elements 114 or the at least partially virtual copies 134. For example, the control parameters 155 entered in the database 154 comprise all control parameters set by means of the first control elements 114 and the copies of the second control elements, from which the currently valid control parameters in each case are selected based on the currently prevailing prioritization. Furthermore, the database 154 defines, for the control elements 114 and copies 134 of the control elements, first prioritizations $N_1, N_2, \dots N_N$ and second prioritizations $F_1, F_2, \dots F_N$. The first prioritizations $N_1, N_2, \dots N_N$, for example, define the settings of the first physical control elements 114 as the only valid control parameters 155 for entry into the database 154 during normal operation of the watercraft. The second prioritizations $F_1, F_2, \dots F_N$, for example, define the settings of the at least partially virtual copies 134 of the second physical control elements associated with the respective second prioritizations $F_1, F_2, \dots F_N$ as the only valid control parameters 155 for entry into the database 154. Such a prioritization can be implemented, for example, through corresponding write permissions. For instance, the first prioritizations $N_1, N_2, \dots N_N$ grant exclusive write permissions to the first simulation environment 110 or the control room 112 of the first simulation

environment 110 for writing valid control parameters 155 to the database 154. For example, the second prioritizations $F_1, F_2, \dots F_N$ grant exclusive write permissions to the technical means 132 of the second simulation environment 130 for writing control parameters 155 to the database 154. A switch between operating modes can occur, for example, by setting a flag 157. If a flag 157 is set for one or more control elements $S_1, S_2, \dots S_N$, then the second prioritizations $F_1, F_2, \dots F_N$ apply to the corresponding control elements $S_1, S_2, \dots S_N$. If no flag 157 is set, then the first prioritizations $N_1, N_2, \dots N_N$ apply to the corresponding control elements $S_1, S_2, \dots S_N$. Alternatively, a switch between operating states can be achieved by overwriting. For example, during normal operation the database 154 contains only the first prioritizations $N_1, N_2, \dots N_N$. In the event of a simulated deviation from the normal operation of the watercraft, the corresponding first prioritizations $N_1, N_2, \dots N_N$ are overwritten by the respective second prioritizations $F_1, F_2, \dots F_N$.

Alternatively, the first prioritizations $N_1, N_2, \dots N_N$ and the second prioritizations $F_1, F_2, \dots F_N$ can each define the activation of the capture of the settings of the first physical control elements 114 or the at least partially virtual copies 134 of the second physical control elements. For example, the first prioritizations $N_1, N_2, \dots N_N$ define that the capture of the settings of the first physical control elements 114 is activated by the simulation environment 110 or the control room 112, while the capture of the settings of the at least partially virtual copies 134 of the second physical control elements is deactivated. In contrast, the second prioritizations $F_1, F_2, \dots F_N$ define, for example, a deactivation of the capture of the settings of the first physical control elements 114, while the capture of the settings of the at least partially virtual copies 134 of the second physical control elements is activated. Again, a switch between first prioritizations $N_1, N_2, \dots N_N$ and second prioritizations $F_1, F_2, \dots F_N$ can be implemented by means of flags or corresponding overwriting.

In addition, the interface 152 comprises state data 156, for example, with state values $Z_1, Z_2, \dots Z_M$ which are calculated by the simulation computer system during the simulated operation of the watercraft. For example, the simulation computer system 150 executes a state simulation program that calculates the states 156 of the watercraft using a digital model 158 of the watercraft and the current control parameters 155. To calculate the current states of the watercraft in the form of state data 156, the simulation program uses, for example, the most recently calculated state values as initial values. If a change occurs, the most recently calculated state values are overwritten with the corresponding updated state values. The corresponding state data 156 can be retrieved by the first simulation environment 110 or control room 112, as well as by the second simulation environment 130 or technical means 132 over the network 170, to display the current state of the watercraft to the respective crew members in the first simulation environment 110 and the second simulation environment 130.

Figure 2 shows a first exemplary simulation environment 110. The simulation environment 110 is arranged, for example, on a movable platform 116. Actuators 118,

such as hydraulic, pneumatic, and/or electrical actuators, are arranged on the platform 116 and configured to reproduce the movements of the watercraft during simulated operation. In the first simulation environment 110, a first group 117 of crew members 115 is located for training in the first simulation environment 110. To train the individual crew members 115 of the first group 117, the first simulation environment 110 comprises a control room 112 equipped with one or more consoles 113, for example. The consoles may also comprise one or more first physical control elements 114, for example. These first physical control elements may be, for example, control elements on the console like a touch display, a trackball, and/or one or more buttons. In addition, or alternatively, the first simulation environment 110 may comprise one or more first physical control elements 114 independent of the control room 112. These first physical control elements 114 may be switches or valves, for example. During the simulated operation of the watercraft, the crew members 115 can use the first physical control elements 114 to set control parameters which are then captured and communicated to a simulation interface. Based on the control parameters set using the first physical control elements 114, any necessary state changes of the watercraft are calculated and represented as part of the simulation. The corresponding states can be reproduced, for example, via displays on the consoles 113 of the control room 112 and/or via the actuators 118.

Figure 3 shows an exemplary second simulation environment 130 for training a second group 137 of crew members 135. Individual crew members 135 are each provided with technical means 132 configured to provide a visual simulation. This visual simulation comprises at least partially virtual copies 134 of second control elements. For example, one or more of the second control elements are identical to one or more of the first control elements 114 of the first simulation environment 110, and/or one or more of the second control elements differ, for example, from one or more of the first control elements 114 of the first simulation environment 110 but are configured to set the same control parameter as a corresponding first control element 114 of the first simulation environment 110. The visual simulation may, for example, comprise the area of the watercraft simulated in the first simulation environment 110. Alternatively, the visual simulation may not include the area of the watercraft simulated in the first simulation environment 110. Furthermore, the visual simulation can include additional areas of the watercraft. The technical means 132 may comprise, for example, smart glasses that enable a complete virtual simulation, within which a crew member 135 can interact with the virtual components of the simulation by means of gesture control and/or one or more controllers. For example, the technical means 132 comprise a screen that can display the completely virtual simulation, within which a crew member 135 can control an avatar by means of corresponding input devices. For example, the technical means comprise a mobile, portable device in the form of a tablet that reproduces a complete virtual simulation in which a crew member 135 can control an avatar by means of the tablet. For example, the technical means 132 comprise an augmented reality device, such as in the form of smart glasses that are configured to complement a tactile element 182 included in the technical means 132 with virtual

components of the corresponding second control element in virtual form. This has the advantage of allowing the corresponding crew member 135 to train the haptic properties of the corresponding second control element, which are physically simulated by the tactile element 182. Complementary components of the second control element that are not included in the tactile element 182 are provided in virtual form. In addition, the environment in which the corresponding second control element is located can also be displayed in virtual form.

Figure 4a shows an example of a first control element 114 in physical form. By way of example, a first physical control element 114 is shown in the form of a valve with a handwheel for manual operation. Figure 4b shows a virtual copy 134 of a second physical control element. This second physical control element is, for example, identical to the first control element 114 from Figure 4a. The virtual copy is, for example, a complete virtual 3D model of the corresponding physical control element 114 from Figure 4a. Finally, Figure 4c shows a partially virtual copy 134 of a second control element, which is, for example, identical to the first physical control element 114 from Figure 4a. In the case of the partially virtual copy 134, a tactile element 182 in the form of a handwheel for opening and closing the respective valve is provided. A crew member training the operation of the corresponding control element using the partially virtual copy 134 can grasp and physically rotate the tactile element 182, as a result of which, for example, the haptic properties of the physical control element 114 from Figure 4a are physically reproduced. The corresponding tactile element 182 is supplemented by additional components 182 in virtual form, creating a visual impression for the corresponding crew member operating the partially virtual copy 134 of the second physical control element, which visual impression is, for example, identical to the visual impression of the physical control element 114 from Figure 4a. Furthermore, the haptic properties when operating the underlying second physical control element are also mimicked by the partially virtual copy 134 through the tactile element 182.

Figure 5 shows the control room 112 in schematic form. The control room 112 comprises a processor 120 and a memory 121 with program instructions 122. By executing the program instructions 122, the processor 120 of the control room 112 is controlled to provide and perform the functions of the control room. For this purpose, the control room comprises a user interface 123 which comprises input and output devices, allowing a crew member to use the control room to control the watercraft through the user interface 123. Furthermore, the control room 112 comprises an interface for the output and input of communication signals. For example, the control room 112 can send control signals to components of the watercraft and receive feedback on the state of the corresponding components of the watercraft. Within the simulation system, the interface 124 is used for communication via the network 170, for example with technical means 132 of the second simulation environment 130 and/or with a simulation computer system 150. In addition, the control room 112 comprises one or more first physical control elements 114.

Figure 6 shows a schematic representation of an exemplary technical means 132. The technical means 132 comprises a processor 140 and a memory 141 containing program instructions 142. Execution of the program instructions 142 by the processor 141 causes the processor 141 to enable the technical means 132 to provide functions for a crew member. For this purpose, the technical means 132 comprises a user interface 143 with output devices. The user interface 143 allows the crew member to interact with the technical means 132. In the memory 141 of the technical means 132, a complete or partial virtual model is stored, for example, for providing at least partially virtual copies 134 of one or more second control elements. This can be, for example, a complete virtual 3D model of the corresponding second control element or complementary components of the corresponding second control element in virtual form. The technical means 132 is configured to provide a crew member using the technical means 132 with a visual simulation using the user interface 134. This visual simulation comprises the respective at least partially virtual copies 134 of the second control elements. The user interface 134 also enables the crew member to interact with the provided at least partially virtual copy 134. In addition, the technical means 132 comprise, for example, communication interfaces 144 for communication with external components, for example with other technical means 132, via the network 170 with the first simulation environment 110 and/or via the network 170 with a simulation computer system 150.

Figure 7 shows the exemplary simulation computer system 150. The simulation computer system 150 comprises a processor 160 and a memory 161 with program instructions 162. The program instructions 162 are configured to control the simulation computer system 150 through the processor 160. For example, the program instructions 162 comprise a state simulation program. The simulation computer system may comprise a user interface 136, for example, that allows a user to interact with the simulation computer system 150. Furthermore, the simulation computer system 150 comprises a communication interface 164 that enables the simulation computer system 150 to communicate with other components of the simulation system, such as the control room 112 of the first simulation environment 110 or the technical means 132 of the second simulation environment 132, for example via a communication network 178. In addition, the memory of the simulation computer system 150 comprises, for example, a database 154, in which the current control parameters 155 set by means of the first physical control elements 114 and the at least partially virtual copies 134 of the second control elements are stored. In addition, the database 154 comprises state data 156 of the watercraft, for example, which were calculated for the simulated operation of the watercraft using the current control parameters 155, for example by a state simulation program. The simulation computer system 150 provides the corresponding current control parameters 155 and the state data 156, for example, for retrieval by external components, such as the control room 112 of the first simulation environment 110 and/or the technical means 132 of the second simulation environment 130.

Figure 8 shows a method for writing current control parameters to the simulation interface. In block 200, the simulation interface receives a write request to write a control parameter. The corresponding write request may relate to a control parameter set by means of a first physical control element or to a control parameter set by means of an at least partially virtual copy of a second physical control element. In block 202, it is determined, for example, whether normal operation or a deviation from normal operation is present. This check may be based, for example, on a flag. If a corresponding flag is not set, it may, for example, indicate normal operation. If a corresponding flag is set, it may indicate a deviation from normal operation. If it is determined in block 202 that the simulated operation of the watercraft is normal, the process continues in block 204. In this case, a write permission based on the first prioritization is checked to write the requested control parameter. If the check is positive, the corresponding control parameter is written into the simulation interface in block 208. If the check is negative, writing the control parameter is denied, and the write request from block 200 is rejected. If it is determined in block 202 that the simulated operation of the watercraft involves a deviation from normal operation, i.e. a simulated deviation from normal operation, the process continues in block 206. In block 206, write permissions for the write request are checked based on the second prioritizations. If the check is positive, the process continues in block 208, and the corresponding control parameter is written into the simulation interface. If the check is negative, writing the control parameter is denied, and the write request from block 200 is rejected. This method is repeatedly executed, for example, for write requests during the simulated operation of the watercraft. For instance, a corresponding write request is made each time a control parameter setting is changed during training using a first control element or an at least partially virtual copy of a second control element. During the simulated operation, there may be a change in block 210 from normal operation to a deviation from normal operation, or vice versa. Subsequent write requests in block 200 are then checked, taking into account the corresponding change in operation.

Figure 9 shows a method for selecting current control parameters in the simulation interface from written control parameters. In this case, both control parameters set by means of the first physical control elements, i.e. first control parameters, and control parameters set by means of copies of the second control elements, i.e. second control parameters, are used. For example, the simulation environments are each assigned interface parameters into which the corresponding simulation environments are allowed to write according to interface definitions. The simulation environments can write their set control parameters into these interface parameters at any time. A flag that distinguishes between first prioritization, e.g. remote control, and second prioritization, e.g. local control, signals to the simulation model which of the interface values should be adopted as the valid control parameter for the simulation of the watercraft. For instance, if the flag is set to normal operation, and the second simulation environment writes an opening degree of a virtual copy of a valve in the virtual environment

into the simulation interface, this control parameter will exist as a value in the simulation interface or in one of the interface parameters assigned to the second simulation environment but will not be adopted or used as a valid control parameter for the simulation.

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In block 250, both the first and second control parameters are written into the simulation interface. In block 252, it is determined, for example, whether normal operation or a deviation from normal operation is present. A check of this kind is performed, for example, upon a read request to retrieve the currently valid control parameters for the simulation of the watercraft. This check can be based, for example, on a flag. If a corresponding flag is not set, it may indicate normal operation, for example. If a corresponding flag is set, it may indicate a deviation from normal operation. If it is determined in block 252 that the simulated operation of the watercraft is normal, the process continues in block 254. In this case, the first control parameters are selected, for example, based on the first prioritization. If it is determined in block 202 for one or more of the control elements or associated control parameters that the simulated operation of the watercraft involves a deviation from normal operation, i.e. a simulated deviation from normal operation, the process continues in block 256. In block 256, the second control parameters are selected, which were set using the copies of the second control elements associated with the second prioritizations of the deviation from normal operation. In block 258, the selected first and/or second control parameters are read and used as the currently valid control parameters for the simulation of the watercraft. During the simulated operation, there may be a change in operation in block 260 from normal operation to a deviation from normal operation, or vice versa. Subsequent read requests when initiating block 252 are then checked, taking into account the corresponding change in operation.

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Figure 10 shows a method for changing operations based on the activation and deactivation of the detection of settings of the first physical control parameters and the at least partially virtual copies. If the detection by means of a first physical control parameter is deactivated, it is not possible, for example, to set an assigned control parameter using the corresponding first control element. If the detection by means of a copy of a second physical control parameter is deactivated, it is not possible, for example, to set an assigned control parameter by means of the corresponding copy. For example, the corresponding copy cannot be operated at all as long as the first prioritizations apply to it. In block 300, there is a change in operation from normal operation to a deviation from normal operation, or vice versa. Subsequently, the operation-specific detection of control parameter settings is activated. In normal operation, the capture of physical control parameter settings is activated, while the settings of the at least partially virtual copies of the physical control parameters is deactivated. During a simulated deviation from normal operation, the detection of settings of the first physical control elements is deactivated, while the detection of settings of the at least partially virtual copies of the second physical control elements whose setting detection is activated are recorded. In block 304, the control parameters of those

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control elements whose setting detection is activated are recorded. In the case of normal operation, the settings of the physical control parameters are recorded; in the case of a deviation from normal operation, the settings of the at least partially virtual copies of the second physical control elements are recorded. In block 306, the recorded control parameters are written into the simulation interface. The method continues in block 304. Changes to the settings of control elements for which detection is activated are recorded in block 304 and written into the simulation interface in block 306. If there is another change in operation from the deviation from normal operation to normal operation or vice versa, the method continues with block 300.

Figure 11 shows an exemplary method for simulating states of a watercraft. In block 400, current state data for the watercraft are accessed. The corresponding current state data may result from a previous simulation step. In block 402, current control parameters for the watercraft are accessed. These control parameters are set, for example, by means of first physical control elements or at least partially virtual copies of second physical control elements. In block 404, the current state of the watercraft is simulated using the state data from block 400 and the control parameters from block 402, based on a digital model of the watercraft. This is carried out, for example, by a state simulation program. The results of the corresponding simulation are used in block 406 to update the state data. The method is then cyclically repeated, for example, starting with block 400. For example, the method is repeated each time a control parameter changes.

Independently of the updating of the state data, i.e. asynchronously to blocks 400 to 406, the updated state data can be read by other components of the simulation system in block 408. For example, the updated state data are read from the simulation interface by a first simulation environment or the control room in the first simulation environment, as well as by the second simulation environment or the technical means of the second simulation environment. In block 410, the read state data are processed and, for example, displayed to the crew members as part of the training. The method then continues with block 408 as needed or cyclically.

Figure 12 shows an exemplary simulation system 100 that corresponds to the simulation system 100 from Figure 1. The exemplary simulation system 100 comprises a first simulation environment 110 and a second simulation environment 130. In addition, the simulation system 100 comprises a simulation computer system 150, which provides a simulation interface 152. The different components of the simulation computer system 100, i.e. the first simulation environment 110, the second simulation environment 130, and the simulation computer system 150, are communicatively connected to one another by means of communications links over a communications network 170. The difference as compared with the simulation system 100 from Figure 1 is that the first simulation environment 110 from Figure 12 is not arranged on a movable platform. Therefore, it is an unmovable, i.e. static, simulation environment 110.

Figure 13 shows an exemplary simulation system 100, which comprises a first simulation environment 110 and a second simulation environment 130. The first simulation environment 110 with a control room 112 that comprises a plurality of consoles 113, for example, is arranged on a movable platform 116. The platform 116 is moved by means of a plurality of actuators. These actuators may be hydraulic, pneumatic, and/or electrical actuators, for example. The platform 116 is, for example, arranged in an elevated position to provide sufficient movement clearance relative to the floor 103 beneath the platform 116, so that tilting movements can be carried out, for example. The first simulation environment 110 arranged on the elevated platform 116 can be accessed, for example, via a ladder 104 and/or a static platform or walkway 102. For example, the first simulation environment 110 is arranged in a hall.

The second simulation environment 130 is arranged in an adjoining room, for example, and comprises technical means 132 configured to provide a visual simulation with at least partial virtual copies of first physical control elements. The corresponding technical means 132 may be one or more desktop PCs, portable mobile devices such as tablets, or smart glasses, for example. In Figure 13, the technical means 132 are provided in the form of a plurality of desktop PCs.

Finally, the simulation system 100 also comprises a server room 106 with the simulation computer system 150, which comprises one or more servers, for example, and provides a simulation interface. In the memory of the simulation interface or the simulation computer system 150, a database is stored containing definitions of the one or more first control elements and the one or more copies of the second control elements. The definitions for the specified control elements and copies each set a first prioritization for a simulated normal operation of the watercraft. In addition, the simulation interface of the simulation computer system 150 is configured to switch from the first prioritizations of the one or more first control elements and the one or more copies of the second control elements to one or more second prioritizations in response to a simulated malfunction of the watercraft.

Figure 14 provides a detailed view of the exemplary first simulation environment 110 from Figure 13 with a control room 112 which comprises a number of consoles 113. The first simulation environment 110 is arranged on a movable platform 116. The platform 116 is moved by means of a plurality of actuators, for example. The actuators are, for example, hydraulic, pneumatic, and/or electrical actuators. The platform 116 is arranged in an elevated position, for example, to provide sufficient movement clearance relative to the floor 103 beneath the platform 116, so that tilting movements can be carried out. The first simulation environment 110 arranged on the elevated platform 116 can be accessed, for example, via a ladder 104 and/or a static platform or walkway 102.

Figure 15 shows exemplary consoles 113 within a first simulation environment. These consoles 113 are, for example, components of a control station 112 arranged in the

first simulation environment. Figure 15 displays a group of three consoles 113, for example. Each console 113 comprises a computer unit 14, a display and control unit 18, a display screen 26, and a touch-sensitive screen 36, for example. The consoles 113 may feature a projecting board 10 which extends from the front side of the respective console 113 facing the user. The board is positioned, for example, between two compartments, i.e. below a compartment for the console 113 for the display and control unit 18 and above a compartment for the computer unit 14. The board holds, for example, the touch-sensitive screen 36 and an additional selection device 28. The computer unit 14 is arranged below the board 10, for example in a compartment of the console 113. The computer unit 14 controls the display and control unit 18, for example, and processes user inputs captured by the display and control unit 18.

The display and control unit 18 comprises a screen 26, for example, for displaying states and/or functions of the watercraft. For example, at least parts of a digital model of the watercraft are presented on the screen 26. The display and control unit 18 also comprises a touch-sensitive screen 36, for example, such as for displaying executable actions or functions of the watercraft that can be initiated. The touch-sensitive screen 36 is divided into touch-sensitive areas 38, for example, each representing a selectable action. A user can select a touch-sensitive area 38, for example, by touching the corresponding area 38. The areas 38 may each be rectangular in shape. For example, the areas 38 are arranged side by side and one below the other in rows and columns on the screen 36, without overlapping. In addition, the screen 36 on the board 10 may also have one or more non-touch-sensitive areas, for example, for notifications to the user to be displayed.

The display and control unit 18 also comprises one or more input means, such as the selection device 28, for recording user inputs. The selection device 28 is mounted in the board 10, for example. In addition, the selection device 28 comprises a trackball 29 and one or more buttons 30, for example.

The consoles 113 also comprise, for example, an instrument panel 34 with indicator lights showing specific operating states of components of the watercraft. These instrument panels 34 are arranged, for example, in compartments of the consoles 113, such as above the display and control unit 18.

The display and control unit 18 captures user inputs, such as the selection of an object of the watercraft displayed on the screen 26. User inputs can be captured using the selection device 28 and/or the touch-sensitive screen 36. Based on the captured user inputs, the display and control unit 18 communicates to the computer unit 14 which component the user has selected. For example, the display and control unit 18 may issue a confirmation signal after the user has made a selection. The confirmation signal may be, for example, the illumination of an indicator light on the instrument panel 34 or another visual, auditory, or tactile signal, such as a highlighting of the selected component on the screen 26 or a vibration, for example, from the selection device 28,

such as the trackball 29. This confirmation signal indicates to the user that their selection has been registered.

5 In response to the selection of an object on the screen 26, and therefore the corresponding component of the watercraft, the computer unit 14 determines which actions can be performed on the selected component represented by the selected object. The corresponding component may, for example, be a valve of the subsystem of the watercraft displayed on the screen 26, such as a cooling system. The computer unit 14 then reads from an accessible table, in which possible actions for this selected component are stored. The computer unit 14 then prompts the display and control unit 18
10 to generate an actions display and show it on the touch-sensitive screen 36.

This actions display shows the determined actions that can be performed on the component represented by the selected object on the screen 26. The actions display of
15 the possible actions is therefore context-dependent, as it depends on which object in the display on the screen 26, and therefore which component, was previously selected.

List of reference signs

	10	Board
5	14	Computer unit
	18	Display and control unit
	26	Screen
	28	Selection device
	29	Trackball
10	30	Buttons
	34	Instrument panel
	36	Touch-sensitive screen
	38	Touch-sensitive screen area
	100	Simulation system
15	102	Static platform
	103	Floor
	104	Ladder
	106	Server room
	110	First simulation environment
20	111	Motion control
	112	Control room
	113	Console
	114	Physical control element
	115	Crew member
25	116	Movably mounted platform
	117	First group of crew members
	118	Actuators
	120	Processor
	121	Memory
30	122	Instructions
	123	User interface
	124	Communication interface
	130	Second simulation environment
	132	Technical means
35	134	Copy of a control element
	135	Crew member
	137	Second group of crew members
	140	Processor
	141	Memory
40	142	Instructions
	143	User interface
	144	Communications interface
	150	Simulation computer system
	152	Simulation interface

	154	Database
	155	Control parameter
	156	State data
	157	Flag
5	158	Digital model of the watercraft
	160	Processor
	161	Memory
	162	Instructions
	163	User interface
10	164	Communications interface
	170	Network
	180	Virtual 3D model of a control element
	182	Tactile element
	184	Virtual components of the control element copy
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Claims

1. A simulation system (100) for simultaneously training a plurality of crew members (115, 135) of a military watercraft, wherein the simulation system (100) comprises a first simulation environment (110) with a physical control room (112) of the watercraft for training a first group (117) of crew members (115),

wherein the first simulation environment (110) comprises one or more first physical control elements (114) of the watercraft, wherein the first physical control elements (114) are each configured to set one or more control parameters (155) for operating the watercraft,

wherein the control room (112) is configured to record the control parameters (155) set by means of the first physical control elements (114) and to communicate them to a simulation interface (152) of the simulation system (100),

wherein the simulation system (100) further comprises a second simulation environment (130), spatially separate from the first simulation environment (110), for training a second group (137) of crew members (135), wherein the second simulation environment (130) comprises technical means (132) configured to provide a visual simulation that comprises one or more at least partially virtual copies (134) of one or more second physical control elements (114) of the watercraft for setting the control parameters (155),

wherein the technical means (132) are also configured to record the control parameters (155) set by means of the copies (134) and to communicate them to the simulation interface (152) of the simulation system (100),

wherein the simulation interface (152) of the simulation system (100) comprises a memory, wherein a database (154) containing definitions of one or more first physical control elements (114) and one or more copies (134) of one or more second control elements is stored, wherein the definitions for the defined first control elements (114) and copies (134) of the second control elements each establish a first prioritization for simulated normal operation of the watercraft, in which the settings of the control parameters (155) according to the first physical control elements (114) are prioritized as the exclusively valid control parameter (155) settings for the simulation of the watercraft over the settings according to the copies (134) of the second control elements,

wherein the simulation interface (152) of the simulation system (100) is further configured to switch from one or more first prioritizations to one or more second prioritizations in response to a simulated deviation from the normal operation of the watercraft, wherein the one or more second prioritizations prioritize, for the simulated deviation from normal operation, the settings of one or more control parameters (155) according to one or more copies (134) of the second control elements associated with the second prioritizations over the settings according to one or more first physical control elements (114) associated with the second prioritizations as the exclusively valid settings of the corresponding control parameters (155) for the simulation of the watercraft.

2. The simulation system (100) as claimed in claim 1, wherein the first simulation environment (110) is arranged on a movably mounted platform (116), wherein a plurality of hydraulic, pneumatic, and/or electric actuators (118) is arranged on the platform (116), which are controlled by a motion control system (111) of the platform (116) to simulate the movements of the watercraft during the simulated operation.

3. The simulation system (100) as claimed in any one of claims 1 to 2, wherein the memory of the simulation interface (152) further stores the control parameters (155) currently valid for the simulation of the watercraft.

4. The simulation system (100) as claimed in claim 3, wherein the first prioritizations and the second prioritizations each define write permissions for writing control parameters (155) into the memory of the simulation interface (152).

5. The simulation system (100) as claimed in claim 4, wherein the first prioritizations each specify that the control room (112) of the first simulation environment (110) has write permissions for writing the control parameters (155) set by means of the first physical control elements (114) which are valid in the simulated normal operation of the watercraft, while the technical means (132) of the second simulation environment (130) do not have write permissions for writing the control parameters (155) currently valid for the simulation of the watercraft,

wherein the second prioritizations specify that the technical means (132) of the second simulation environment (130) have write permissions to write the control parameters (155) set by means of the copies (134) of the second control elements associated with the second prioritizations and valid in the simulated deviation from normal operation of the watercraft, while the control room (112) does not have write permissions to write the control parameters (155) that are set by means of the first physical control elements (114) associated with the second prioritizations as the control parameters (155) currently valid for the simulation of the watercraft.

6. The simulation system (100) as claimed in claim 4, wherein both the control room (112) of the first simulation environment (110) has write permissions to write the control parameters (155) set by means of the first physical control elements (114), and the technical means (132) of the second simulation environment (130) have write permissions to write the control parameters (155) set by means of the copies (134) of the second control elements,

wherein the first prioritizations specify that the control parameters (155) set by means of the first physical control elements (114) and written by the control room (112) are read as the control parameters (155) valid in the simulated normal operation of the watercraft, while the control parameters (155) set by means of the copies (134) of the second control elements and written by the technical means (132) of the second simulation environment (130) are not read,

wherein the second prioritizations specify that the control parameters (155) set by means of the copies (134) of the second control elements associated with the

second prioritizations and written by the technical means (132) of the second simulation environment (130) are read as the control parameters (155) valid for the simulated deviation from normal operation of the watercraft, while the control parameters (155) set by means of the first physical control elements (114) associated with the
5 second prioritizations and written by the control room (112) are not read.

7. The simulation system (100) as claimed in any one of claims 1 to 3, wherein the first prioritizations specify that the capture of control parameters (155) set by means of the first physical control elements (114) by the control room (112) in the first
10 simulation environment (110) is enabled, while the capture of control parameters (155) set by means of the copies (134) of the second control elements by the technical means (132) of the second simulation environment (130) is disabled,

wherein the second prioritizations specify that the capture of control parameters (155) set by means of the copies (134) of the second control elements is enabled
15 by the technical means (132) of the second simulation environment (130), while the capture of the control parameters (155) set by means of the first physical control elements (114) by the control room (112) in the first simulation environment (110) is disabled.

8. The simulation system (100) as claimed in any one of the preceding claims, wherein the copies (134) of the second control elements are each a complete virtual 3D model (180) of the respective second control element, wherein the technical means (132) in the second simulation environment (130) comprise one or more output devices with one or more displays for visual output of the virtual 3D models (180), as
20 as well as one or more input means for the virtual simulation of operating the virtual 3D models (180) for providing copies (134) of the second control elements.

9. The simulation system (100) as claimed in any one of claims 1 to 7, wherein the technical means (132) in the second simulation environment (130) for providing
30 copies (134) of the second control elements comprise one or more tactile elements (182) to physically reproduce the haptic characteristics of one or more second control elements, and wherein the technical means (132) also comprise one or more augmented reality devices which are configured to provide complementary components (184) of the corresponding second control elements in virtual form to the tactile elements (182), wherein the one or more augmented reality devices each comprise one
35 or more displays for visual output of the complementary virtual components (184) of the copies (134) of the second control elements and one or more sensors to capture interactions by the crew members (135) of the second group (137) of crew members (135) using the one or more augmented reality devices with the tactile elements (182)
40 and/or the complementary virtual components (184) when operating the copies (134) of the second control elements.

10. The simulation system (100) as claimed in any one of the preceding claims, wherein the one or more first control elements (114) comprise one or more valves, switches, and/or touch-sensitive elements of the watercraft, and/or

5 wherein the second control elements comprise one or more valves, switches, and/or touch-sensitive elements of the watercraft.

11. The simulation system (100) as claimed in claim 10, wherein the one or more first control elements (114) each comprise a mechanically operable component, and/or

10 wherein the one or more second control elements comprise a mechanically operable component.

12. The simulation system (100) as claimed in any one of the preceding claims, wherein the first simulation environment (110) comprises a physical operations center of the watercraft, wherein the first simulation environment (110) comprises, for example, a physical bridge of the watercraft.

13. The simulation system (100) as claimed in any one of the preceding claims, wherein the simulation interface (152) is provided by a simulation computer system (150) that comprises a memory (161) with executable program instructions (162) of a state simulation program for simulating a state of the watercraft and a digital model (158) of the watercraft, as well as a processor (160), wherein execution of the program instructions (162) by the processor (160) causes the simulation computer system (150) to simulate a current state of the watercraft using the digital model (158) of the watercraft and the control parameters (155) valid for the watercraft simulation.

14. The simulation system (100) as claimed in any one of the preceding claims, wherein a switch from the simulated normal operation of the watercraft to the simulated deviation from normal operation of the watercraft occurs when an external command to switch is received via the simulation interface (152).

15. The simulation system (100) as claimed in any one of claims 1 to 12, wherein a switch from the simulated normal operation of the watercraft to the simulated deviation from normal operation of the watercraft occurs automatically via the simulation interface (152) as part of the execution of the state simulation program, if the simulated state of the watercraft involves a malfunction.

16. The simulation system (100) as claimed in any one of the preceding claims, wherein the simulated deviation from normal operation of the watercraft includes a failure of the first group (117) of crew members (115).

17. The simulation system (100) as claimed in any one of the preceding claims, wherein the military watercraft is one of the following: a submarine, an aircraft carrier, a helicopter carrier, a cruiser, a destroyer, a frigate, a corvette, a landing ship, a

minelayer, a mine clearance vessel, a mine hunter, a patrol boat, a fast attack craft, or a reconnaissance ship.

18. A computer-based method for operating a simulation system (100) for simultaneously training a plurality of crew members (115, 135) of a military watercraft, wherein the simulation system (100) comprises a first simulation environment (110) with a physical control room (112) of the watercraft for training a first group (117) of crew members (115),

wherein the first simulation environment (110) comprises one or more first physical control elements (114) of the watercraft, each first physical control element (114) configured to set one or more control parameters (155) for the operation of the watercraft,

wherein the control room (112) is configured to detect the control parameters (155) set by means of the first physical control elements (114) and to communicate them to a simulation interface (152) of the simulation system (100),

wherein the simulation system (100) also comprises a second simulation environment (130), spatially separate from the first simulation environment (110), for training a second group (137) of crew members (135), wherein the second simulation environment (130) comprises technical means (132) which are configured to provide a visual simulation that comprises one or more at least partially virtual copies (134) of one or more second physical control elements of the watercraft for setting control parameters (155),

wherein the technical means (132) are also configured to record the control parameters (155) set by means of the copies (134) and to communicate them to the simulation interface (152) of the simulation system (100),

wherein the simulation interface (152) of the simulation system (100) comprises a memory, in which a database (154) containing definitions of one or more first control elements (114) and one or more copies (134) of one or more second control elements is stored, wherein the definitions for the defined first control elements (114) and copies (134) of the second control elements each establish a first prioritization for simulated normal operation of the watercraft, in which the settings of the control parameters (155) according to the first physical control elements (114) are prioritized as the exclusively valid settings of the control parameters (155) for the simulation of the watercraft over the settings according to the copies (134) of the second control elements,

wherein the method involves:

switching from one or more first prioritizations to one or more second prioritizations in response to a simulated deviation from the normal operation of the watercraft, wherein the one or more second prioritizations prioritize, for the deviation from normal operation, the settings of one or more control parameters (155) according to one or more copies (134) of the second control elements associated with the second prioritizations over the settings according to one or more first physical control elements (114) associated with the second prioritizations as the only valid settings of the corresponding control parameters (155) for the simulation of the watercraft.