



(11)

EP 4 545 399 A1

(12)

EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
30.04.2025 Bulletin 2025/18

(51) International Patent Classification (IPC):
B63C 11/00 ^(2006.01) **B63C 11/48** ^(2006.01)

(21) Application number: **23826927.8**

(52) Cooperative Patent Classification (CPC):
B63C 11/00; B63C 11/48

(22) Date of filing: **31.05.2023**

(86) International application number:
PCT/JP2023/020222

(87) International publication number:
WO 2023/248740 (28.12.2023 Gazette 2023/52)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(72) Inventors:
• **OKAYA, Noriyuki**
Chuo-ku, Kobe-shi
Hyogo 650-8670 (JP)
• **FUKUI, Koichi**
Chuo-ku, Kobe-shi
Hyogo 650-8670 (JP)

(30) Priority: **21.06.2022 JP 2022099740**

(74) Representative: **Leinweber & Zimmermann**
Patentanwalts-PartG mbB
European Patent Attorneys
Viktualienmarkt 8
80331 München (DE)

(71) Applicant: **KAWASAKI JUKOGYO KABUSHIKI KAISHA**
Kobe-shi, Hyogo 650-8670 (JP)

(54) **UNDERWATER TOWING SYSTEM**

(57) An underwater towing system (1) according to one embodiment includes: a towing structure (2) sailing on or in water; a towing rope (3) hanging down from the towing structure (2) into the water; and underwater work structures (5) towed by the towing rope (3). At least one light emitter (4) is attached to the towing rope (3). The light emitter (4) is controlled by control circuitry (21) included in the towing structure (2). Each of the underwater work

structures (5) includes a light receiver (53) that can receive a light signal from the light emitter (4). One of the underwater work structures (5) separates from the towing rope (3) when the control circuitry (21) makes the light emitter (4) transmit a separation signal for this underwater work structure (5), and the light receiver (53) of this underwater work structure (5) receives the separation signal.

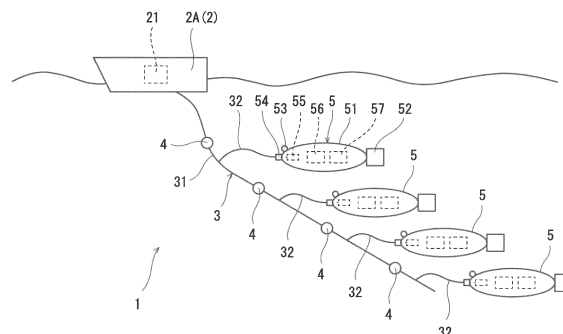


FIG. 1

EP 4 545 399 A1

Description

Technical Field

[0001] The present disclosure relates to an underwater towing system that tows underwater work structures in water.

Background Art

[0002] Underwater work structures, such as an autonomous underwater vehicle (AUV; also called an unmanned underwater vehicle (UUV)) and underwater observation equipment, have been known. For example, PTL 1 describes that to investigate a large water area, AUVs are put into water from a support ship.

Citation List

Patent Literature

[0003] PTL 1: Japanese Laid-Open Patent Application Publication No. 2018-172056

Summary of Invention

Technical Problem

[0004] However, when the support ship is rocking hard by influence of wind, waves, or the like, it is difficult to put the underwater work structures into water from the support ship.

[0005] An object of the present disclosure is to provide an underwater towing system that can locate underwater work structures at target places.

Solution to Problem

[0006] The present disclosure provides an underwater towing system including: a towing structure sailing on or in water and including control circuitry; a towing rope hanging down from the towing structure into the water; at least one light emitter attached to the towing rope and controlled by the control circuitry; and underwater work structures towed by the towing rope, wherein: each of the underwater work structures includes a light receiver that receives a light signal from the at least one light emitter; and one of the underwater work structures separates from the towing rope when the control circuitry makes the at least one light emitter transmit a separation signal for this underwater work structure, and the light receiver of this underwater work structure receives the separation signal.

Advantageous Effects of Invention

[0007] The present disclosure provides the underwater towing system that can locate the underwater work

structures at the target places.

Brief Description of Drawings

[0008]

FIG. 1 is a schematic configuration diagram of an underwater towing system according to one embodiment.

FIG. 2 is a schematic configuration diagram of the underwater towing system according to a modified example.

FIG. 3 is a schematic configuration diagram of the underwater towing system according to another modified example.

Description of Embodiments

[0009] FIG. 1 shows an underwater towing system 1 according to one embodiment. The underwater towing system 1 includes a towing structure 2 and underwater work structures 5. In the present embodiment, the towing structure 2 is a support ship 2A that sails on water.

[0010] A towing rope 3 hangs down from the towing structure 2 into water. The underwater work structures 5 are towed by the towing rope 3. In the present embodiment, the towing rope 3 includes: a main line 31 connected to the towing structure 2; and branch lines 32 that extend from the main line 31 and are used for connection with the underwater work structures 5. However, the branch lines 32 are not necessarily required, and the underwater work structures 5 may be directly connected to the main line 31.

[0011] At least one light emitter 4 is attached to the towing rope 3. The light emitter 4 is, for example, a LED. In the present embodiment, the light emitters 4, the number of which is equal to the number of underwater work structures 5, are attached to the main line 31 of the towing rope 3. However, the number of light emitters 4 does not necessarily have to be equal to the number of underwater work structures 5 and may be smaller or larger than the number of underwater work structures 5. Moreover, the light emitters 4 may be attached to not the main line 31 of the towing rope 3 but the branch lines 32 or may be attached to both of the main line 31 and the branch lines 32.

[0012] The towing structure 2 includes first control circuitry 21 configured to control the light emitters 4. To be specific, the first control circuitry 21 is electrically connected to all of the light emitters 4. In the present embodiment, the first control circuitry 21 makes all of the light emitters 4 transmit light signals of the same flashing pattern such that all of the light emitters 4 flash in synchronization with each other. To be specific, the flashing pattern includes: information indicating which of the underwater work structures 5 a command is directed to; and a content of the command.

[0013] Regarding the first control circuitry 21 and be-

low-described second control circuitry 56, the functionality of the elements disclosed herein may be implemented using circuitry or processing circuitry which includes general purpose processors, special purpose processors, integrated circuits, ASICs ("Application Specific Integrated Circuits"), conventional circuitry and/or combinations thereof which are configured or programmed to perform the disclosed functionality. Processors are considered processing circuitry or circuitry as they include transistors and other circuitry therein. In the disclosure, the circuitry, units, or means are hardware that carry out or are programmed to perform the recited functionality. The hardware may be any hardware disclosed herein or otherwise known which is programmed or configured to carry out the recited functionality. When the hardware is a processor which may be considered a type of circuitry, the circuitry, means, or units are a combination of hardware and software, the software being used to configure the hardware and/or processor.

[0014] The number of underwater work structures 5 is four in the illustrated example but may be two, three, or five or more. In the present embodiment, the underwater work structures 5 are AUVs. Specifically, each underwater work structure 5 that is the AUV includes: a main body 51 having a streamline shape; and a propulsor 52 located at the main body 51.

[0015] The propulsor 52 can apply thrust to the main body 51 in a front-rear direction, left-right direction, and upper-lower direction of the main body 51. In addition, the propulsor 52 can apply turning force to the main body 51 in a yaw direction around an upper-lower axis of the main body 51 and a pitch direction around a left-right axis of the main body 51. For example, the propulsor 52 may include thrusters that are directed in different directions from each other or may include a single thruster of a swing type.

[0016] A light receiver 53, an engager 54, and an actuator 55 are located at a front portion of the main body 51. The light receiver 53 can receive the light signal from the light emitter 4. The engager 54 can be connected to the branch line 32 of the towing rope 3. The actuator 55 operates the engager 54. Moreover, the second control circuitry 56 and an inertial navigation system 57 (INS) are located at the main body 51.

[0017] The second control circuitry 56 is electrically connected to the light receiver 53, the actuator 55, and the inertial navigation system 57. The second control circuitry 56 reads the command from the first control circuitry 21 in such a manner that the light receiver 53 receives the light signal when the light signal from the light emitter 4 includes the command directed to the underwater work structure 5 on which this second control circuitry 56 is mounted.

[0018] The engager 54 includes, for example, a hook that can swing. In this case, the actuator 55 makes the hook swing. The actuator 55 is controlled by the second control circuitry 56.

[0019] The inertial navigation system 57 includes: ac-

celerometers that detect respective accelerations in directions in which three axes orthogonal to each other extend; and gyro sensors that detect respective angular velocities around the three axes. The inertial navigation system 57 calculates a movement direction of the main body 51 from a reference position of the main body 51 and a movement distance of the main body 51 from the reference position of the main body 51, and calculates a current posture of the main body 51. After the underwater work structure 5 separates from the towing rope 3, the second control circuitry 56 controls the propulsor 52 based on calculation results of the inertial navigation system 57.

[0020] Next, control performed by the first control circuitry 21 and the second control circuitry 56 will be described in detail.

[0021] When the towing structure 2 reaches a target place of each underwater work structure 5, the first control circuitry 21 makes the light emitter 4 transmit a separation signal for the underwater work structure 5 to be located. The target places of all of the underwater work structures 5 may be the same as each other or may be different from each other.

[0022] The second control circuitry 56 of each underwater work structure 5 determines based on the flashing pattern of the light signal received by the light receiver 53 whether or not the light signal is the separation signal for this underwater work structure 5. When the light receiver 53 of each underwater work structure 5 receives the separation signal for this underwater work structure 5, the second control circuitry 56 drives the actuator 55 such that the towing rope 3 and the engager 54 are disconnected from each other. Thus, the underwater work structure 5 separates from the towing rope 3.

[0023] As described above, according to the underwater towing system 1 of the present embodiment, the underwater work structures 5 are towed by the towing rope 3 that hangs down from the towing structure 2 into water. Therefore, the underwater work structures 5 can be conveyed to the target places by the sailing of the towing structure 2. Moreover, when each underwater work structure 5 is conveyed to the target place, and the first control circuitry 21 makes the light emitter 4 transmit the separation signal for the underwater work structure 5, the underwater work structure 5 separates from the towing rope 3 at the target place. Therefore, the underwater work structures 5 can be located at the target places.

Modified Examples

[0024] The present disclosure is not limited to the above embodiment, and various modifications may be made within the scope of the present disclosure.

[0025] For example, the underwater work structures 5 may include respective light emitters, and light receivers corresponding to these light emitters may be attached to the towing rope 3 and electrically connected to the first

control circuitry 21. According to this configuration, information can be output from the underwater work structures 5 to the first control circuitry 21. In this case, it is desirable that the color of the light signal transmitted from the light emitter 4 of the towing rope 3 and the color of the light signal transmitted from the light emitter of the underwater work structure 5 be different from each other. It is desirable that when the light emitters of all of the underwater work structures 5 emit light in the same color, the light emission of the light emitter of each underwater work structure 5 be controlled by a light emission permission command supplied from the first control circuitry 21 of the towing structure 2 for this underwater work structure 5.

[0026] Moreover, as in an underwater towing system 1A according to a modified example shown in FIG. 2, the towing structure 2 may be an AUV 2B that sails in water. The AUV 2B includes a battery larger than that of the AUV that is the underwater work structure 5. The AUV 2B can sail in water for a long period of time. Moreover, the AUV 2B includes: a main body 22 having a streamline shape; and a propulsor 23 located at the main body 22. The first control circuitry 21 and an inertial navigation system 24 are located at the main body 22.

[0027] Moreover, as in an underwater towing system 1B according to another modified example shown in FIG. 3, each underwater work structure 5 may not include the engager 54 and the actuator 55. In this case, the underwater work structure 5 that is the AUV is towed by the towing rope 3 by sailing while being guided by the light signal from the light emitter 4. When the underwater work structures 5 are guided by the light signals from the light emitters 4, the number of light emitters 4 and the number of underwater work structures 5 may be equal to each other or may be different from each other as with the above.

[0028] According to this configuration, the underwater work structures 5 can be indirectly towed by the towing rope 3 without being connected to the towing rope 3. On the other hand, in a case where each underwater work structure 5 includes the engager 54 and the actuator 55 as in the above embodiment, when the underwater work structure 5 is towed by the towing rope 3, the underwater work structure 5 can be mechanically connected to the towing rope 3 (direct towing).

[0029] According to the underwater towing system 1B shown in FIG. 3, when the light receiver 53 of each underwater work structure 5 receives the separation signal for this underwater work structure 5 from the light emitter 4, the second control circuitry 56 changes from a following mode in which the underwater work structure 5 sails while following the light emitter 4 to a work mode in which the underwater work structure 5 performs underwater work. Thus, the underwater work structure 5 separates from the towing rope 3.

[0030] Moreover, the underwater work structure 5 does not necessarily have to be the AUV and may be underwater observation equipment. The underwater observation equipment may include a propulsor or may not

include a propulsor.

Conclusion

[0031] As a first aspect, the present disclosure provides an underwater towing system including: a towing structure sailing on or in water and including control circuitry; a towing rope hanging down from the towing structure into the water; at least one light emitter attached to the towing rope and controlled by the control circuitry; and underwater work structures towed by the towing rope, wherein: each of the underwater work structures includes a light receiver that receives a light signal from the at least one light emitter; and one of the underwater work structures separates from the towing rope when the control circuitry makes the at least one light emitter transmit a separation signal for this underwater work structure, and the light receiver of this underwater work structure receives the separation signal.

[0032] According to the above configuration, the underwater work structures are towed by the towing rope hanging down from the towing structure into the water. Therefore, the underwater work structures can be conveyed to the target places by the sailing of the towing structure. Moreover, when each underwater work structure is conveyed to the target place, and the control circuitry makes the light emitter transmit the separation signal for the underwater work structure, the underwater work structure separates from the towing rope at the target place. Therefore, the underwater work structures can be located at the target places.

[0033] As a second aspect, the underwater towing system may be configured such that: in the first aspect, the control circuitry includes first control circuitry; each of the underwater work structures includes an engager that is connectable to the towing rope, an actuator that operates the engager, and second control circuitry configured to control the actuator; and when the light receiver receives the separation signal, the second control circuitry drives the actuator such that the towing rope and the engager are disconnected from each other. According to this configuration, when towing the underwater work structures by the towing rope, the underwater work structures can be mechanically connected to the towing rope.

[0034] As a third aspect, the underwater towing system may be configured such that in the first or second aspect, for example, each of the underwater work structures includes an autonomous underwater vehicle.

[0035] As a fourth aspect, the underwater towing system may be configured such that in the first aspect, each of the underwater work structures includes an autonomous underwater vehicle including a propulsor and is indirectly towed by the towing rope by sailing while being guided by the light signal from the at least one light emitter. According to this configuration, the underwater work structures can be towed by the towing rope without being connected to the towing rope.

Claims

1. An underwater towing system comprising:
 - a towing structure sailing on or in water and including control circuitry; 5
 - a towing rope hanging down from the towing structure into the water;
 - at least one light emitter attached to the towing rope and controlled by the control circuitry; and 10
 - underwater work structures towed by the towing rope, wherein:
 - each of the underwater work structures includes a light receiver that receives a light signal from the at least one light emitter; and 15
 - one of the underwater work structures separates from the towing rope when the control circuitry makes the at least one light emitter transmit a separation signal for this 20
 - underwater work structure, and the light receiver of this underwater work structure receives the separation signal.
2. The underwater towing system according to claim 1, 25
 - wherein:
 - the control circuitry includes first control circuitry;
 - each of the underwater work structures includes 30
 - an engager that is connectable to the towing rope,
 - an actuator that operates the engager, and
 - second control circuitry configured to control the actuator; and 35
 - when the light receiver receives the separation signal, the second control circuitry drives the actuator such that the towing rope and the engager are disconnected from each other. 40
3. The underwater towing system according to claim 1 or 2, wherein each of the underwater work structures includes an autonomous underwater vehicle. 45
4. The underwater towing system according to claim 1, wherein each of the underwater work structures includes an autonomous underwater vehicle including a propulsor and is indirectly towed by the towing rope by sailing while being guided by the light signal from the at least one light emitter. 50

55

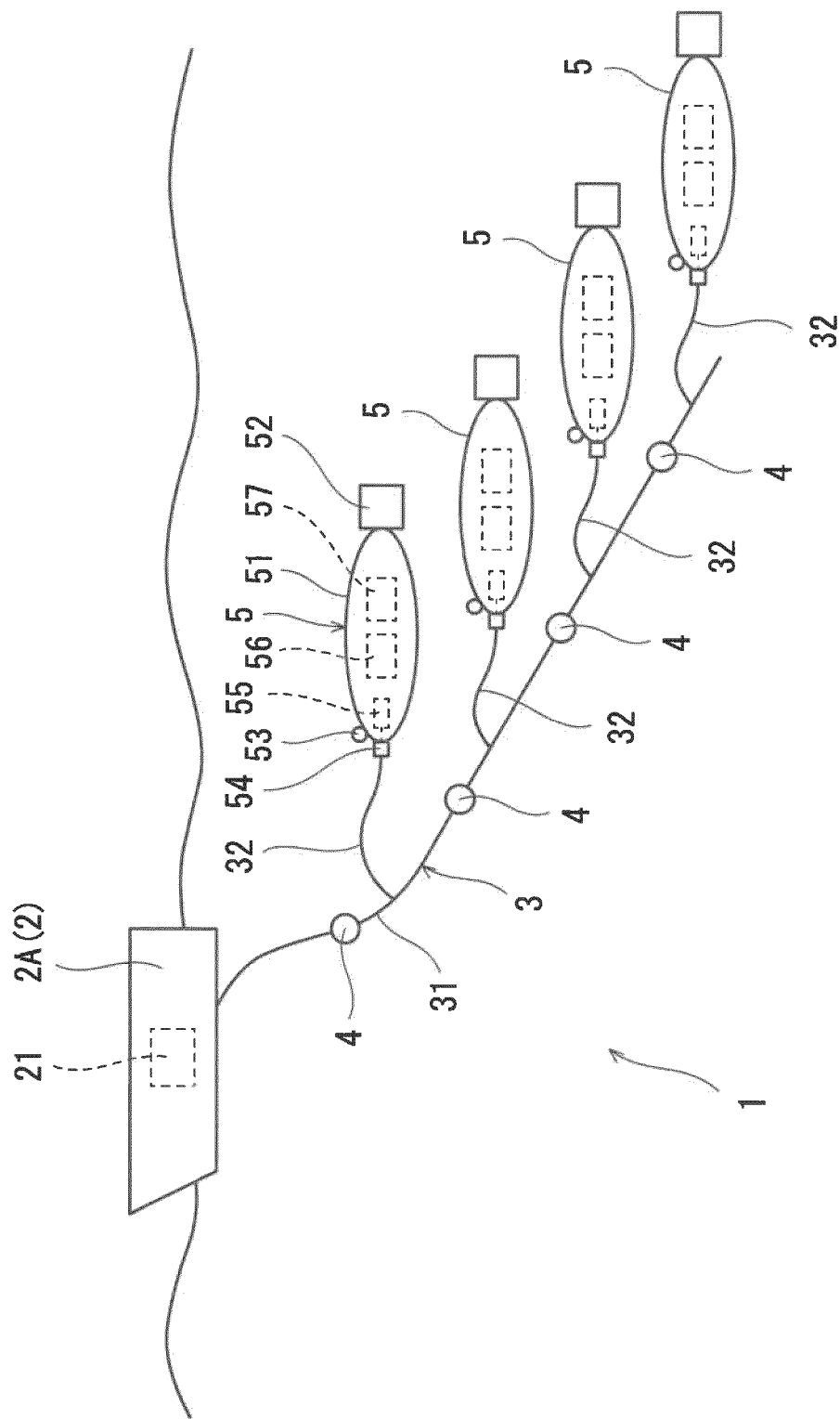


FIG. 1

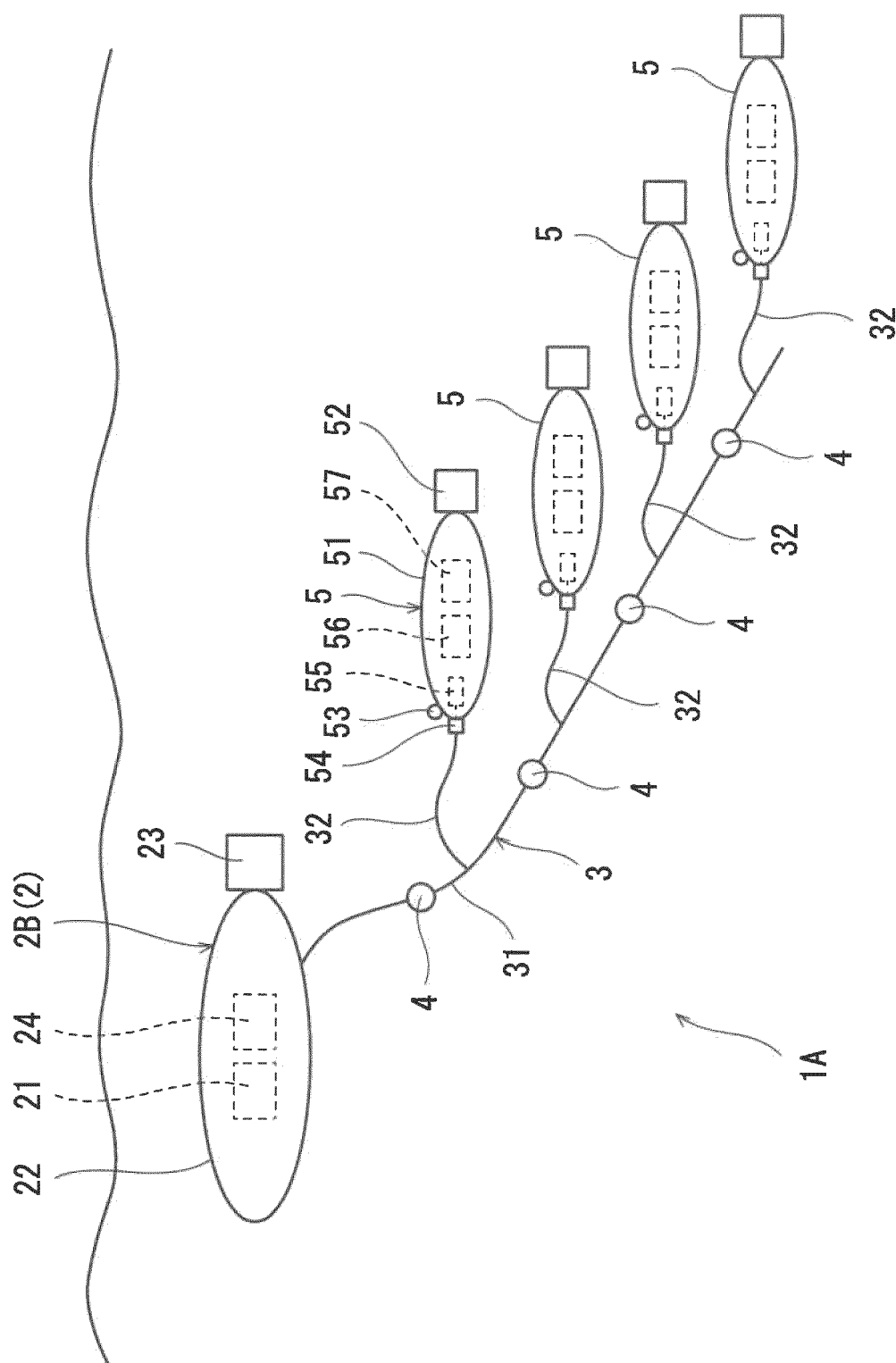


FIG. 2

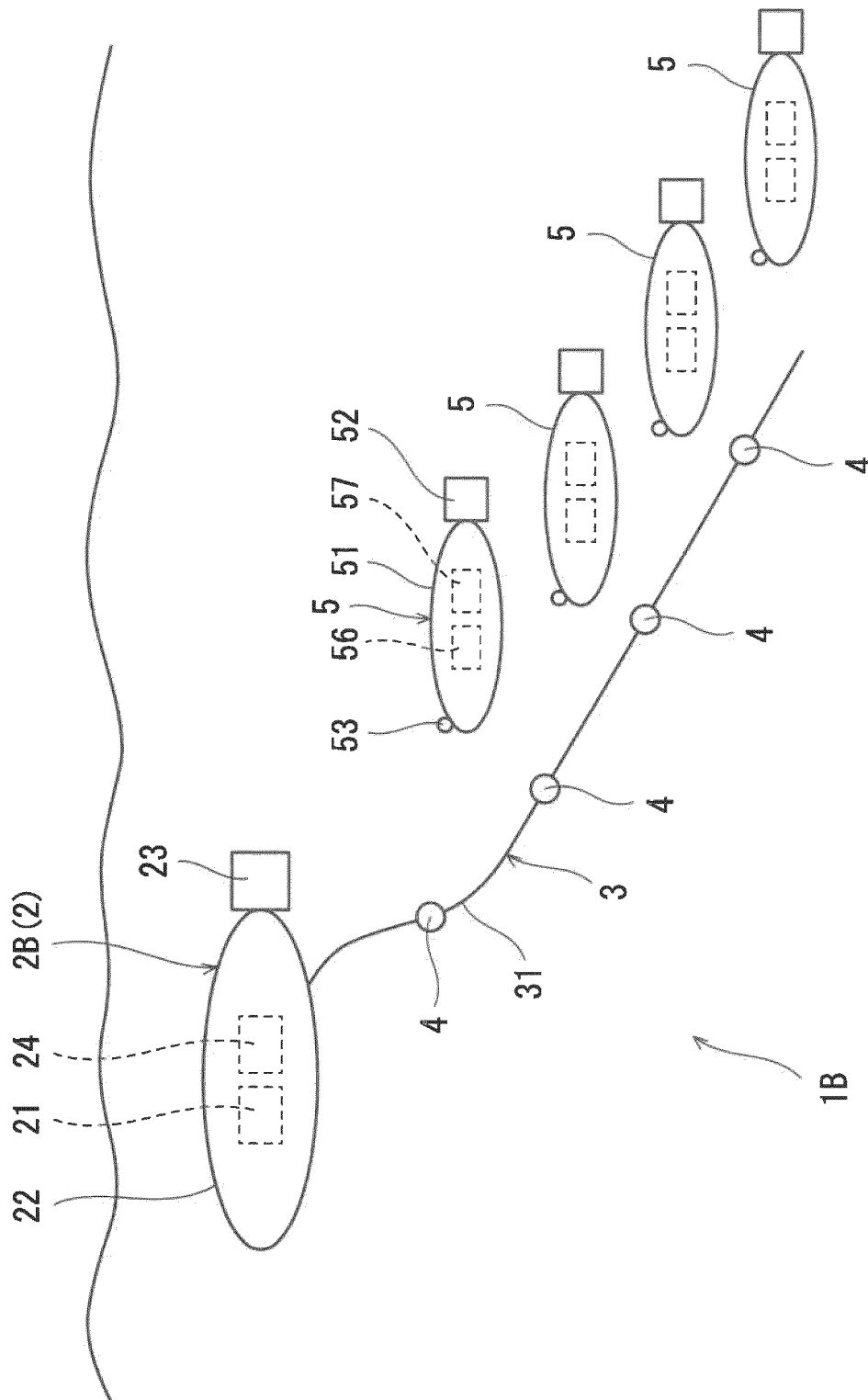


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2023/020222

A. CLASSIFICATION OF SUBJECT MATTER <i>B63C 11/00</i> (2006.01)i; <i>B63C 11/48</i> (2006.01)i FI: B63C11/00 A; B63C11/00 B; B63C11/48 D According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) B63C11/00; B63C11/48		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Published examined utility model applications of Japan 1922-1996 Published unexamined utility model applications of Japan 1971-2023 Registered utility model specifications of Japan 1996-2023 Published registered utility model applications of Japan 1994-2023		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2018-111483 A (NAT UNIV TSING HUA) 19 July 2018 (2018-07-19) paragraphs [0078]-[0177], fig. 32A-E	1-4
A	OHKI, Takeshi. KAKAMI, Hitoshi. NISHIDA, Yuya. NAKATANI, Takeshi. THORNTON, Blair. Development and Testing of an Unmanned Surface Towing System for Autonomous Transport of Multiple Heterogeneous Underwater Vehicles for Seafloor Survey. Marine Technology Society Journal. 2020, vol. 54, no. 5, pp. 61-71, ISSN 0025-3324 entire text, all charts	1-4
A	各務均, 無人海底探査システムの開発と運用, 三井E&S技報, 28 February 2020, no. 3, pp. 1-6, ISSN 2434-4095 entire text, all charts, (KAKAMI, Hitoshi. Development and Operation of Unmanned System for Seafloor Survey. Mitsui E&S group technical review.)	1-4
A	CN 204297038 U (YANG, Yongxin) 29 April 2015 (2015-04-29) entire text, all drawings	1-4
A	KR 10-2007-0034930 A (HOWALDTSWERKE-DEUTSCHE WERFT GMBH) 29 March 2007 (2007-03-29) entire text, all drawings	1-4
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family	
Date of the actual completion of the international search 04 August 2023	Date of mailing of the international search report 15 August 2023	
Name and mailing address of the ISA/JP Japan Patent Office (ISA/JP) 3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915 Japan	Authorized officer Telephone No.	

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2023/020222

C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2010-139270 A (MITSUBISHI HEAVY IND LTD) 24 June 2010 (2010-06-24) entire text, all drawings	1-4
A	TOLBA, Sherif. AMMAR, Reda. Virtual Tether Search: a Self-Constraining Search Algorithm for Swarms in an Open Ocean. 2017 IEEE Symposium on Computers and Communications. IEEE. 2017, pp. 1128-1135, DOI: 10.1109/ISCC.2017.802467, ISBN 978-1-5386-1629-1 entire text, all charts	4
A	金岡秀, 佐藤匠, 今里元信, 稲葉祥梧, 篠野雅彦, 岡本章裕, 藤原敏文, 井上俊司, 複数AUV同時運用による海底調査の現状と今後, 海上技術安全研究所報告, 18 July 2019, vol. 19 separate volume (serial no. 83), pp. 31-34, ISSN 2188-6598 entire text, all charts, (KIN, Koshu. SATO, Takumi. IMASATO, Motonobu. INABA, Shogo. SASANO, Masahiko. OKAMOTO, Akihiro. FUJIWARA, Toshifumi. INOUE, Shunji. Papers of National Maritime Research Institute.), non-official translation (Current status and future of seabed survey using simultaneously operating multiple AUV)	1-4

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/020222

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2018-111483 A	19 July 2018	US 2018/0111665 A1 paragraphs [0078]-[0178], fig. 32	
		TW 201829250 A	
CN 204297038 U	29 April 2015	(Family: none)	
KR 10-2007-0034930 A	29 March 2007	EP 1770822 A1	
		DE 102005045843 A1	
		ES 2552007 T3	
JP 2010-139270 A	24 June 2010	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2018172056 A [0003]