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(54) **Title:** INDEPENDENTLY-MOVEABLE CABLE-MOUNTED APPARATUS

(57) **Abstract:** There is provided a cable-mounted apparatus, a proximal end of the cable mounted to a winch to extend and retract the cable, the apparatus including: a housing connected to a distal end of the cable; a manipulator located underneath the housing; one or more thrusters associated with the housing; and a controller to control actuation of the one or more thrusters to provide independent movement of the apparatus relative to the winch.

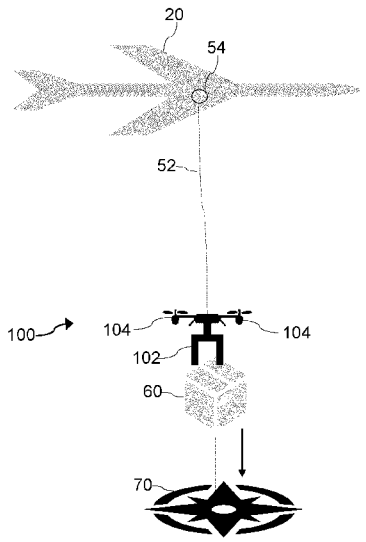


FIG. 3A

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INDEPENDENTLY-MOVEABLE CABLE-MOUNTED APPARATUS

TECHNICAL FIELD

[0001] The following relates generally to cable structures and, more specifically, to an independently-moveable cable-mounted apparatus.

BACKGROUND

[0002] In an example, aircraft may be required to interact with their environment, outside of the aircraft, during flight. In an example that is becoming more common, particularly for rotorcraft, the craft may need to drop off or retrieve cargo mid-flight without having to land. In other cases, tools, such as grippers or manipulators, are used to interact with the environment when located at a distal end of a deployed cable (wire, tether, chain, etc.).

[0003] Generally, due to the nature of the cable, such interactions are limited and simple in nature. Generally, the cable is only semi-rigid so that the cable to be retracted by a winch proximate the rotorcraft. However, this can then cause the cable to sway when deployed, particularly if the distance of the craft to the target is large, causing targeting to be difficult. Additionally, many rotorcraft cann0ot hover in a very precise manner, which could also cause swaying of the cable at the target.

SUMMARY

[0004] In an aspect, there is provided a cable-mounted apparatus, a proximal end of the cable mounted to a winch to extend and retract the cable, the apparatus comprising: a manipulator coupled to the distal end of the cable; one or more thrusters; and a controller to control actuation of the one or more thrusters to provide independent movement of the apparatus relative to the winch.

[0005] These and other aspects are contemplated and described herein. It will be appreciated that the foregoing summary sets out representative aspects of the assembly to assist skilled readers in understanding the following detailed description.

DESCRIPTION OF THE DRAWINGS

[0006] A greater understanding of the embodiments will be had with reference to the Figures, in which:

[0007] FIGS. 1A and 1B are a diagrammatic view of an approach to manipulation during mid-flight;

[0008] FIG. 2 is a diagrammatic view of another approach to manipulation during mid-flight;

[0009] FIGS. 3A and 3B are a diagrammatic view of an apparatus, according to an embodiment, illustrating a delivery of an item from an aircraft;

[0010] FIGS. 4A and 4B are a diagrammatic view of the apparatus of FIGS. 3A and 3B illustrating a retrieval of the item using the aircraft; and

[0011] FIG. 5 is a perspective view of the apparatus of FIGS. 3A and 3B.

DETAILED DESCRIPTION

[0012] Embodiments will now be described with reference to the figures. For simplicity and clarity of illustration, where considered appropriate, reference numerals may be repeated among the Figures to indicate corresponding or analogous elements. In addition, numerous specific details are set forth in order to provide a thorough understanding of the embodiments described herein. However, it will be understood by those of ordinary skill in the art that the embodiments described herein may be practised without these specific details. In other instances, well-known methods, procedures and components have not been described in detail so as not to obscure the embodiments described herein. Also, the description is not to be considered as limiting the scope of the embodiments described herein.

[0013] Various terms used throughout the present description may be read and understood as follows, unless the context indicates otherwise: “or” as used throughout is inclusive, as though written “and/or”; singular articles and pronouns as used throughout include their plural forms, and vice versa; similarly, gendered pronouns include their counterpart pronouns so that pronouns should not be understood as limiting anything described herein to use, implementation, performance, etc. by a single gender; “exemplary” should be understood as “illustrative” or “exemplifying” and not necessarily as “preferred” over other embodiments. Further definitions for terms may be set out herein; these may apply to prior and subsequent instances of those terms, as will be understood from a reading of the present description.

[0014] Any module, unit, component, server, computer, terminal, engine or device exemplified herein that executes instructions may include or otherwise have access to computer readable media such as storage media, computer storage media, or data storage devices (removable and/or non-removable) such as, for example, magnetic disks, optical disks, or tape. Computer storage media may include volatile and non-volatile, removable and non-removable media implemented in any method or technology for storage of information, such as computer readable instructions, data structures, program modules, or other data. Examples of computer

storage media include RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by an application, module, or both. Any such computer storage media may be part of the device or accessible or connectable thereto. Further, unless the context clearly indicates otherwise, any processor or controller set out herein may be implemented as a singular processor or as a plurality of processors. The plurality of processors may be arrayed or distributed, and any processing function referred to herein may be carried out by one or by a plurality of processors, even though a single processor may be exemplified. Any method, application or module herein described may be implemented using computer readable/executable instructions that may be stored or otherwise held by such computer readable media and executed by the one or more processors.

[0015] In embodiments of the present disclosure, there is provided an apparatus that is connected to an aircraft for manipulation of a tool mid-flight, providing better control during deployment. Advantageously, the apparatus is independently-moveable such that the apparatus can make adjustments and movements of the tool without necessarily requiring movement of the aircraft. The aircraft could be an airplane, drone, rotorcraft or other similar device, and is preferable a drone or rotorcraft operable to perform a hovering operation, even if the hovering operation is not entirely precise.

[0016] FIGS. 1A and 1B illustrate an example embodiment 30 of an approach to manipulation during mid-flight. In this example, as shown in FIG. 1A, a cable 52 is deployed and suspended below an aircraft 20 via a winch 54 at the proximal end of the cable 52. At the distal end of the cable 52 is an item 60 attached to the cable 52. As shown in FIG. 1B, when the aircraft 20 approaches a target 70 for item delivery, the winch 54 releases the cable to attempt to have the item 60 land at or near the target 70.

[0017] FIG. 2 illustrates an example embodiment 50 of another approach to manipulation during mid-flight. In this example, a cable 52 is deployed and suspended below the aircraft 20 via a winch 54 at the proximal end of the cable 52. At the distal end of the cable 52 is a gripper tool 56 to release a gripped item 60. In this example, the gripper tool 56 attempts to release the item 60 at or near a target 70.

[0018] In the example embodiments 30 and 50, due to relying on the imprecise movements of the aircraft which is located sufficiently remote from the target 70, there is high imprecision with

respect to placing the item at the target 70. Additionally, such embodiments can only practically drop-off items; and cannot reliably pick-up items from the ground to bring up to the aircraft.

[0019] FIGS. 3A to 5 illustrate a deployable independently-moveable apparatus 100 for aircraft, according to an embodiment. In this embodiment, a cable 52 is deployed and suspended below the aircraft 20 via a winch 54 at the proximal end of the cable 52. The winch 54 is located on or in the aircraft 20. Connected at the distal end of the cable 52 is the apparatus 100.

[0020] The apparatus 100 includes a manipulator 102 and one or more thrusters 104. The manipulator 102 can be any suitable tool to interact with objects or aspects of the environment. In this example embodiment, the manipulator 102 is a gripper tool that can grip and release the item 60. The thrusters 104 advantageously allow for independent movement of the apparatus 100. In this embodiment, the thrusters 104 are a plurality of air thrusters or propellers. In a particular embodiment, the thrusters 104 can be embodied as a secondary rotorcraft with enough thrust to effect relative planar (parallel to the ground) movement of the distal end of the cable relative the aircraft to provide targeting. It will be understood that in the previous sentence, the plane parallel to the ground can be considered the XY plane and that movement of the distal end will cause a pendulum movement of the cable, which has a Z component. In cases where the target is not perfectly centered below the rotorcraft, thrust in the XY plane toward the target would also lift the distal end of the cable along the Z axis away from the target. This movement may be compensated by the winch further extending the cable to reach the target.

[0021] FIGS. 3A and 3B illustrates an example of a delivery of the item 60 to the target 70 using the apparatus 100. In this example, large scale movements are achieved by the aircraft 20 to get the item 60 near the target 70. Once the aircraft 20 is sufficiently close to the target 70, such as close enough to be within range of the length of the cable 52, the winch 54 extends the cable; lowering the apparatus 100 as the manipulator 102 grips the item 60. As the apparatus 100 is lowered by the winch 54, the one or more thrusters 104 provide independent movement along the plane parallel to the ground by adjustment of the thrusting force of the respective thrusters 104. This movement can be automatically controlled by a controller 180 or can be manually controlled via the controller 180. The controller 180 can include one or more processors and a data storage. Automatic control or manual control can be aided by including telemetric sensors such as position sensors, accelerometers and gyroscopes within the controller 180 so that the controller 180 can react to changes in position and orientation of the apparatus 100.

[0022] These movements can be similar in nature to steering of a drone or rotorcraft. In this way, adjustment along the plane parallel to the ground allows the apparatus 100 to accurately place the item 60 at the target 70, as shown in FIG. 3B. In further cases, the thrusters 104 can also move along an axis perpendicular to the ground; for example, to place the package at a target 70 with a specific elevation. When the item 60 arrives at the target 70, the manipulator 102 can release the item 60 for delivery.

[0023] FIGS. 4A and 4B illustrate an example of a retrieval of the item 60 from the target 70 using the apparatus 100. In this example, large scale movements are achieved by the aircraft 20 to get the apparatus 100 near the target 70. Once the aircraft 20 is sufficiently close to the target 70, such as close enough to be within range of the length of the cable 52, the winch 54 extends the cable; lowering the apparatus 100 to the height of the item 60. As the apparatus 100 is lowered by the winch 54, the one or more thrusters 104 provide independent movement along the plane parallel to the ground by adjustment of the thrusting force of the respective thrusters 104. This movement can be automatically controlled by a controller 180 or can be manually controlled via the controller 180. These movements can be similar in nature to steering of a drone or rotorcraft. In this way, adjustment along the plane parallel to the ground allows the apparatus 100 to accurately pick up and grasp the item 60 located at the target 70. When the manipulator 102 of the apparatus 100 arrives at the item 60, the manipulator 102 grasps the item 60. As shown in FIG. 4B, the winch 54 can then retract the cable 52, bringing the item 60 to, or into, the aircraft. In further cases, the thrusters 104 can also move along an axis perpendicular to the ground; for example, to grasp the package at a target 70 with a specific elevation; however, in most cases, the lifting force for retrieving the item 60 is provided by the winch 54.

[0024] As shown in greater detail in FIG. 5, in an embodiment, the apparatus 100 can include four horizontally-oriented air thrusters 104 located inside a housing 106. Attached to the bottom of the housing is the manipulator 102, in this case, a gripper. Attached to the top of the housing is the distal end of the cable 52. The actuation of the thrusters 104 and the manipulator is controlled by the controller 180.

[0025] In some cases, the apparatus 100 may also include sensors, such as a camera system, attached to the housing 106. The sensors can be used for various suitable tasks; for example, identifying the target, identifying the height of the target, identifying the distance to the target, identifying the item, identifying the shape of the item, or the like. In these cases, the information

can be fed back to the controller 180 to control the thrusters 104 of the apparatus 100 or to provide information to a manual operator of the apparatus 100.

[0026] In some cases, the apparatus 100 can be fed power from the aircraft via the cable 52. In other cases, the apparatus 100 can include a battery to power the thrusters 104 and the manipulator 102. In some cases, the battery can be recharged when the apparatus 100 is at the aircraft during retraction of the cable 52.

[0027] While the present embodiments illustrate the apparatus 100 having a gripper as the manipulator 102, it is understood that any suitable tool can be used. Other examples of manipulator 102 can include a grabber, magnet, hook, suction gripper, a winch, a welder, a container with an openable floor, or the like. In some cases, the manipulator 102 may also be in communication with the controller 180 such that the controller 180 can instruct actuation of the manipulator 102; for example, opening and closing of the gripper, or winding and unwinding of the winch. Advantageously, manipulation of the manipulator 102 allows the apparatus 100 to accomplish a variety of useful tasks, such as moving items around a warehouse, delivering items to a residence, detailed retrieval at typically inacceptable locations, or the like. In further examples, the apparatus 100 can be used to paint or conduct inspections of various kinds; for example, using ultrasonic sensors as the manipulator 102. In further embodiments, the manipulator 102 can include a further assembly for finer movements; for example, a three-degrees-of-freedom “delta robot” positioned underneath the housing 106.

[0028] While the present embodiments illustrate the apparatus 100 having air thrusters as the thrusters 104, it is understood that any suitable thruster can be used. Other examples of thrusters 104 can include thrusting turbines, jet thrusters, heated gas thrusters, or the like. The thrusters 104 are suitable if they provide enough thrust to be able to provide precision and accuracy of moving the distal end of the cable, given the weight and geometry of the cable, the apparatus, and the item (if there). Additionally, while the present embodiments illustrate the apparatus 100 having thrusters 104 in a horizontally-oriented dual or quad-copter orientation, it is understood that any suitable orientation can be used; for example, vertically or angled-oriented thrusters, or having more or less thrusters than exemplified.

[0029] The apparatus 100 of the present embodiments provides substantial advantages to manipulators deployed from aircraft. There is generally minimum extra weight added due to the apparatus as the manipulator and thrusters can be, for example, less than 300g. The apparatus 100 allows for pickup and drop off from any suitable height. In these embodiments, in contrast to a pure drone package retrieval system, there are no significant weight limitations since the

winch lifts up the package to a large aircraft. The present embodiments are generally safe because the apparatus is small and the housing can cage the thrusters. The present embodiments allow for precise pickup and drop off of items; and precise use of manipulators more generally. The present embodiments also allow for the reuse of the cable.

[0030] In further embodiments, the apparatus 100 of the present embodiments can be used for any application in which the winch is located substantially above a desired target. For example, at a distal end of a cable line from a crane to the ground, at a distal end of a cable line from a roof of a building to the ground, or the like.

[0031] Although the foregoing has been described with reference to certain specific embodiments, various modifications thereto will be apparent to those skilled in the art without departing from the spirit and scope of the invention as outlined in the appended claims.

CLAIMS

1. A cable-mounted apparatus, a proximal end of a cable mounted to a winch to extend and retract the cable, the apparatus comprising:

a manipulator coupled to a distal end of the cable;

one or more thrusters; and

a controller to control actuation of the one or more thrusters to provide independent movement of the manipulator relative to the winch.

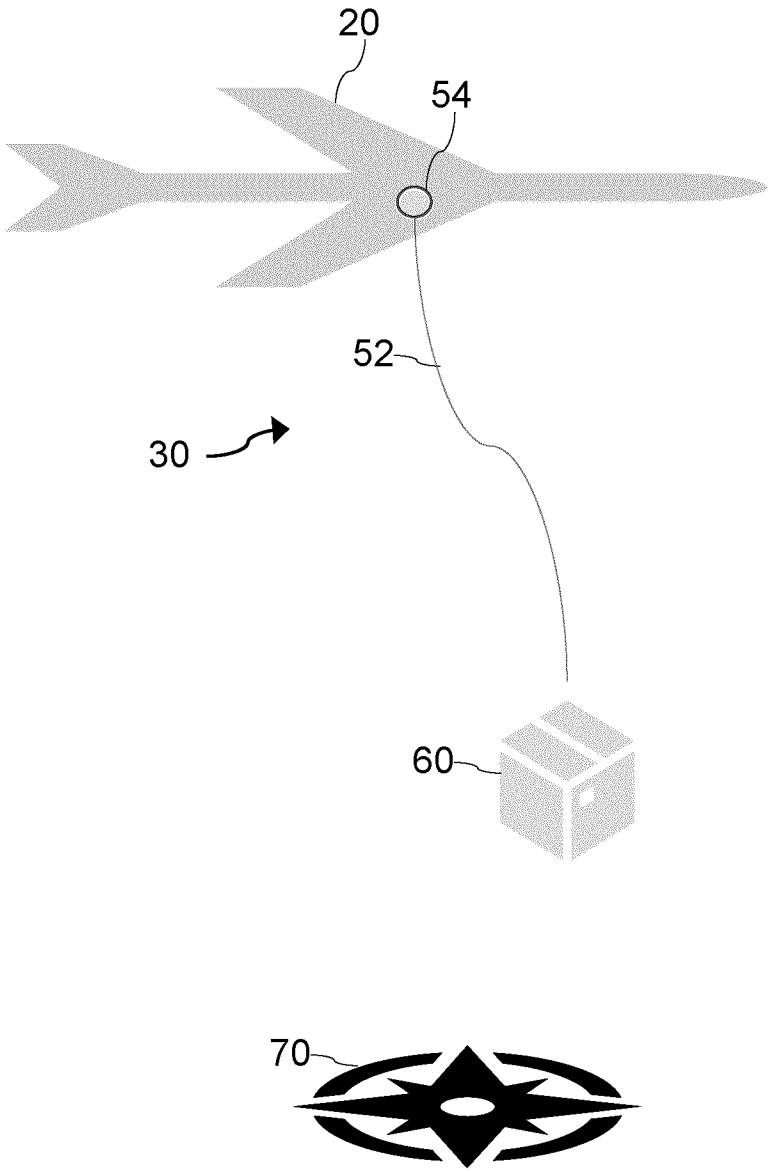


FIG. 1A

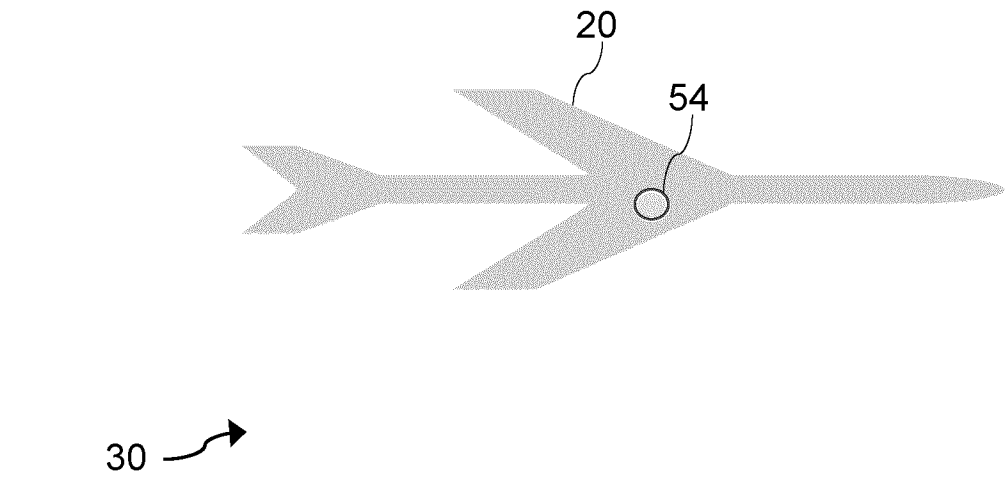


FIG. 1B

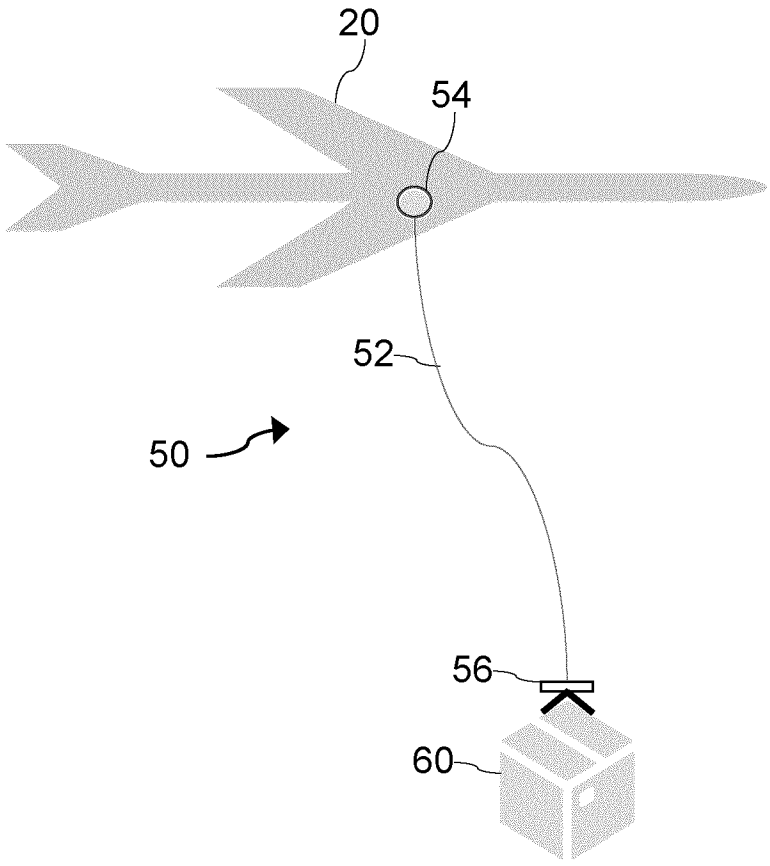




FIG. 2

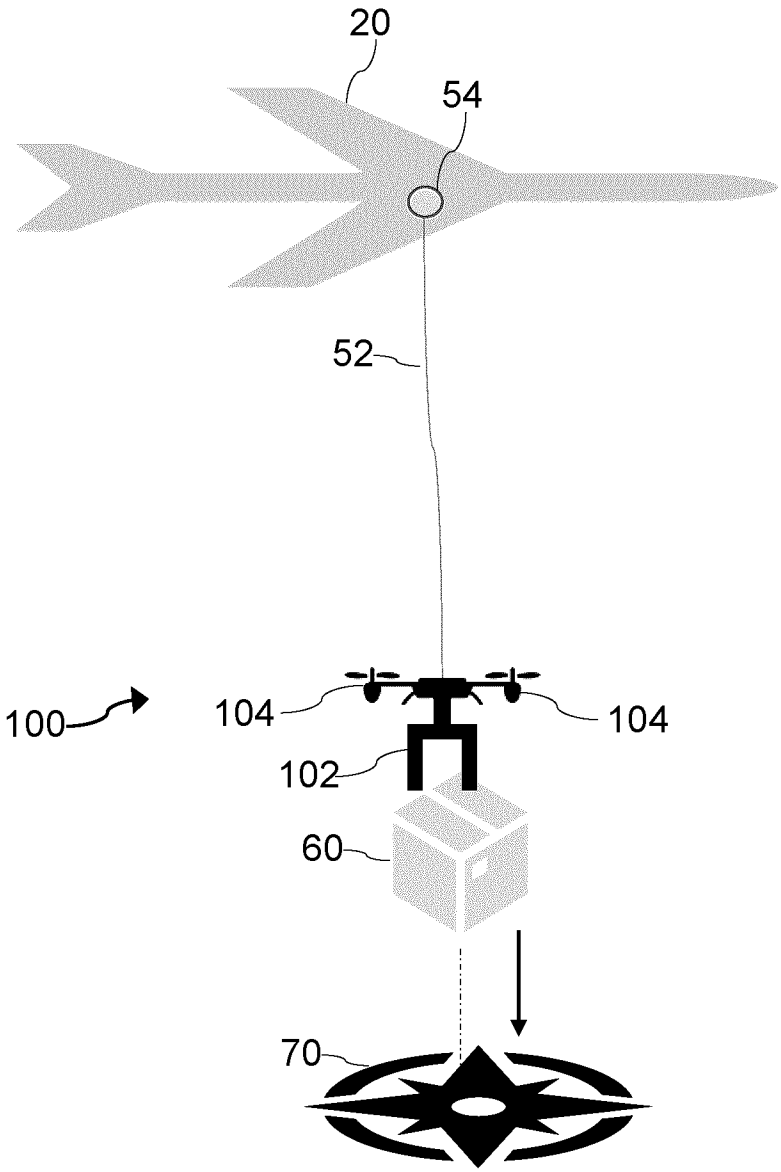


FIG. 3A

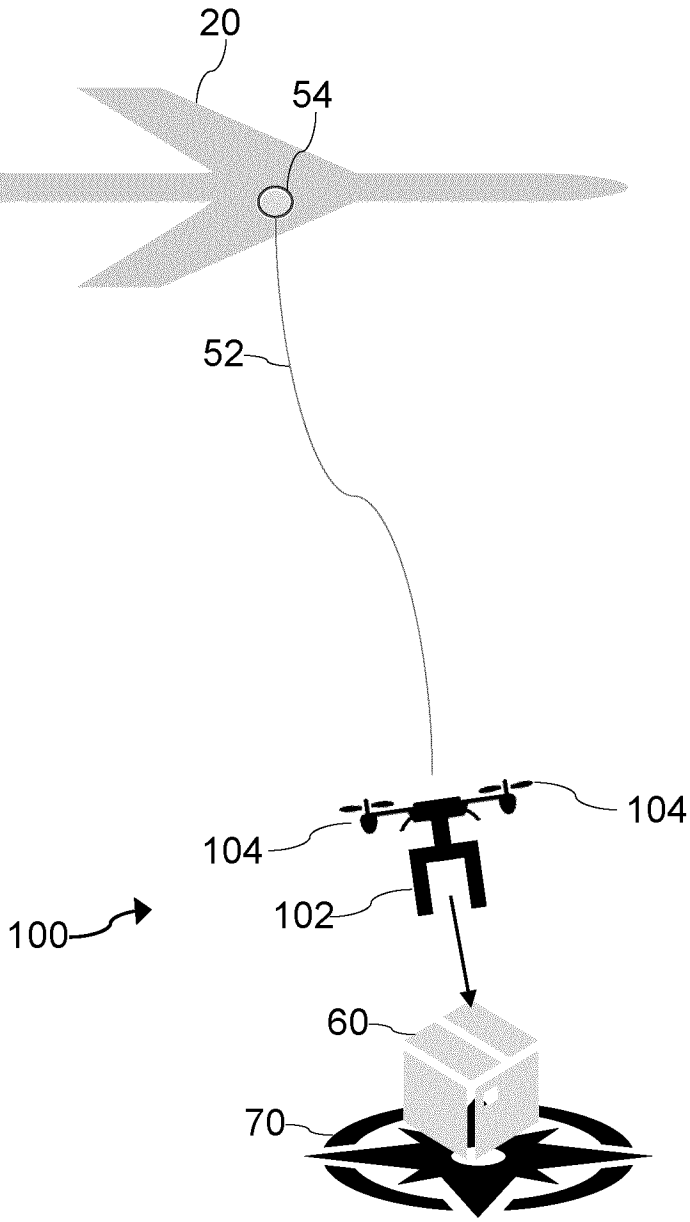


FIG. 3B

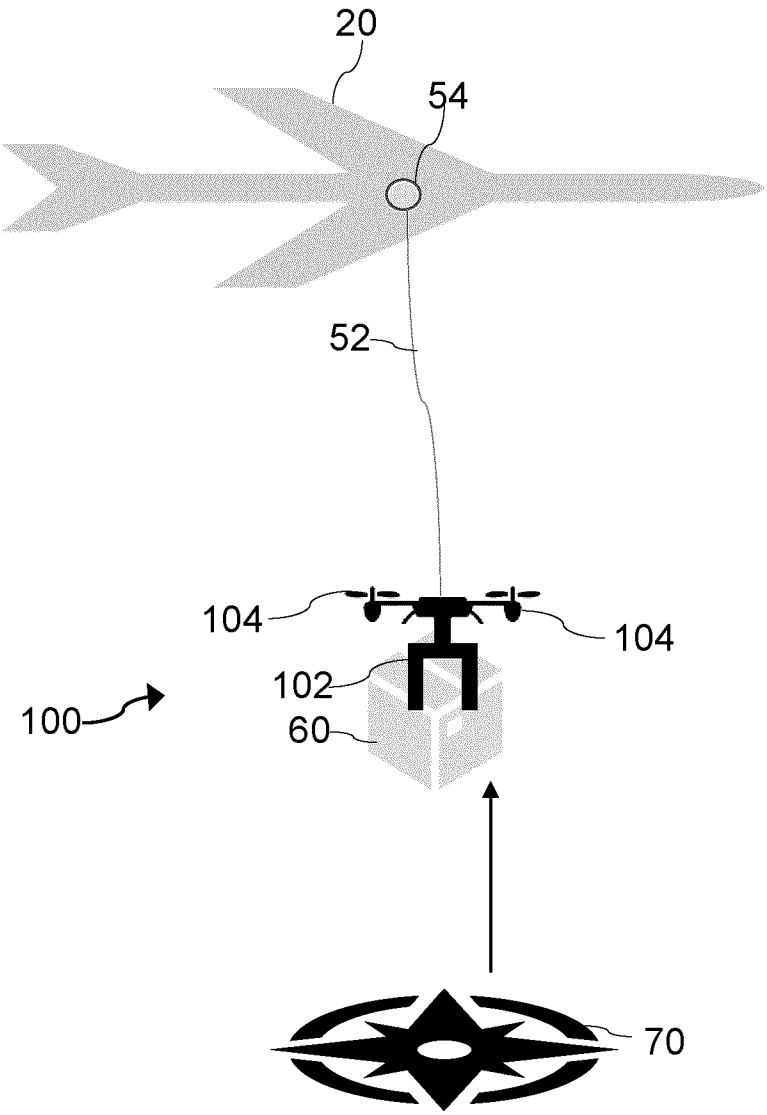


FIG. 4A

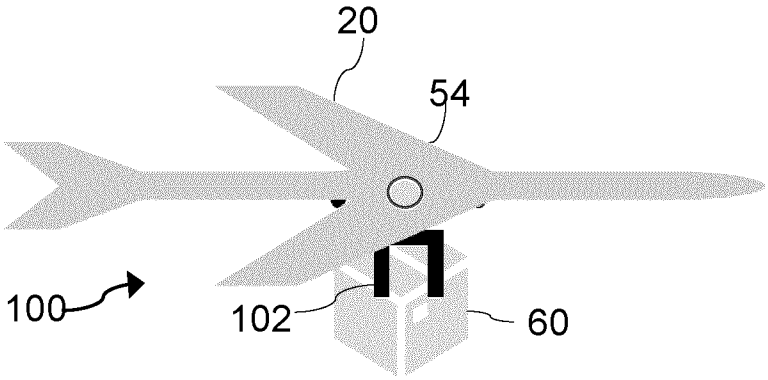




FIG. 4B

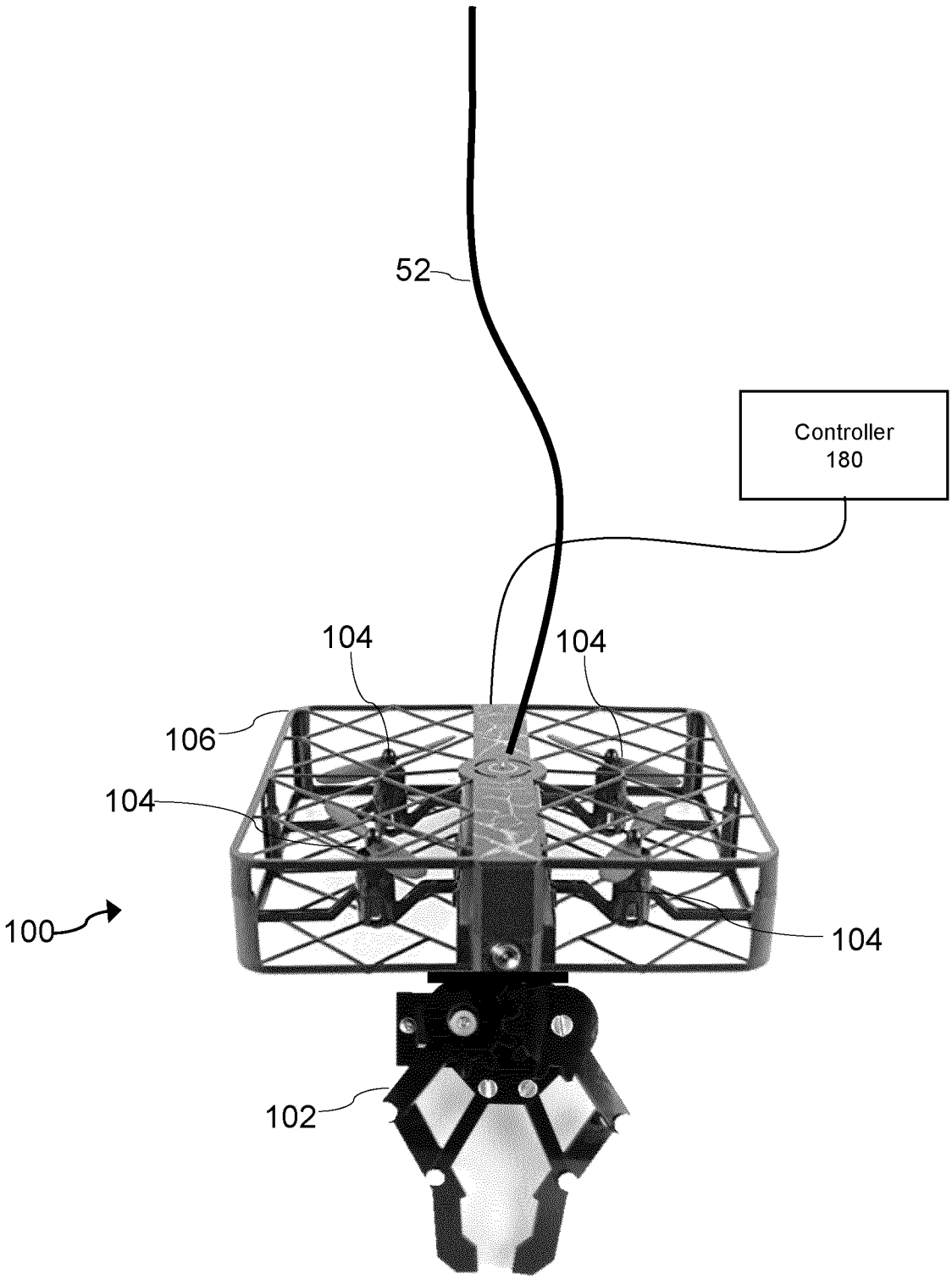


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***B64D 1/02*** (2006.01) , ***B64C 39/02*** (2006.01) , ***B64D 1/22*** (2006.01)

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)
IPC: B64D 1/02 (2006.01) , B64C 39/02 (2006.01) , B64D 1/22 (2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Database: Questel-Orbit
Keywords: cable, tether, suspension line, winch, control, thrust, propeller, blower, fan, manipulator, grip, grasp, grab, magnet, hook, suction, welder, aircraft, airplane, drone, rotorcraft, helicopter.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	JP 09309687 A (ABE, T.) 02 December 1997 (02-12-1997) * The entire document *	1
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☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

*	Special categories of cited documents:	"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
"A"	document defining the general state of the art which is not considered to be of particular relevance	"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
"D"	document cited by the applicant in the international application	"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
"E"	earlier application or patent but published on or after the international filing date	"&"	document member of the same patent family
"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		

Date of the actual completion of the international search 29 May 2020 (29-05-2020)	Date of mailing of the international search report 03 July 2020 (03-07-2020)
Name and mailing address of the ISA/CA Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 819-953-2476	Authorized officer Jean-Francois Goulet (819) 639-1568

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
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