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(56) Documents Cited:
US 20200001988 A1 **US 20200001979 A1**
US 20140145025 A1
KR20130037697

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INT CL **B64C, B64D**
Other: **WPI, EPODOC**

(54) Title of the Invention: **Object detection system**
Abstract Title: **Wireless object proximity detectors mounted on, and powered by rotation of, rotorcraft blades**

(57) A collision avoidance system, suitable for a rotorcraft (a), includes a proximity detector (od) which is mounted on, or forms part of, a rotary blade (fig.1a,1). Also claimed is a rotorcraft, such as a helicopter or gyrocopter, with three or more rotors, each with two or more rotary wings, in which at least one rotary wing has a proximity detector, and the rotorcraft has a means for determining the angular position of rotary wings. Preferably, all the rotary wings have a proximity detector. Also claimed is a helicopter blade object detection system where a blade mounted detector, operating with no physical power or data connection to an aircraft, performs detection of external objects and wirelessly communicates this information to the aircraft. The detector may: be powered via airflow generated on rotation; determine external object range and angular position relative to the aircraft; also receive information from the aircraft; detect objects in a different plane to the wing/blade using roll, pitch, yaw data. Also claimed is an automatic navigation system, suitable for a rotorcraft, with positional sensors on one or more rotary wings. Preferably, a target location is set and the rotorcraft manoeuvres around objects autonomously using positional data as input.

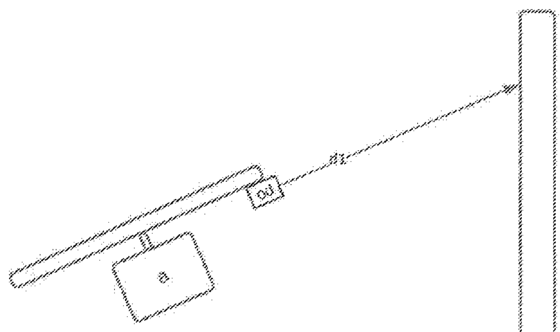

Figure 3 (a)

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

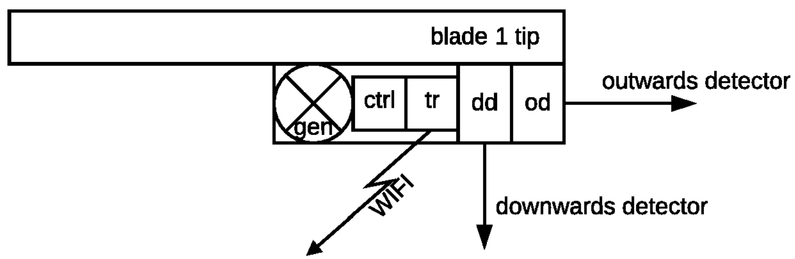

Figure 1 (a)

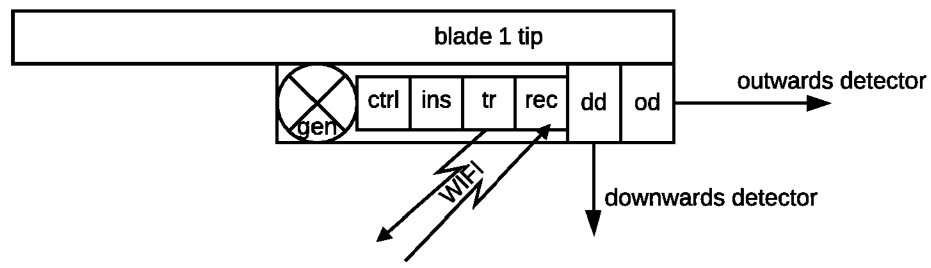

Figure 1 (b)

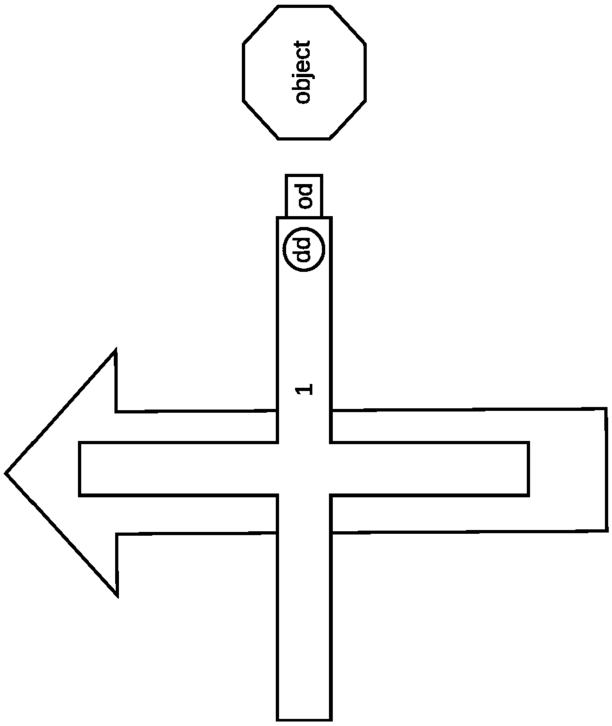

Figure 2 (b)

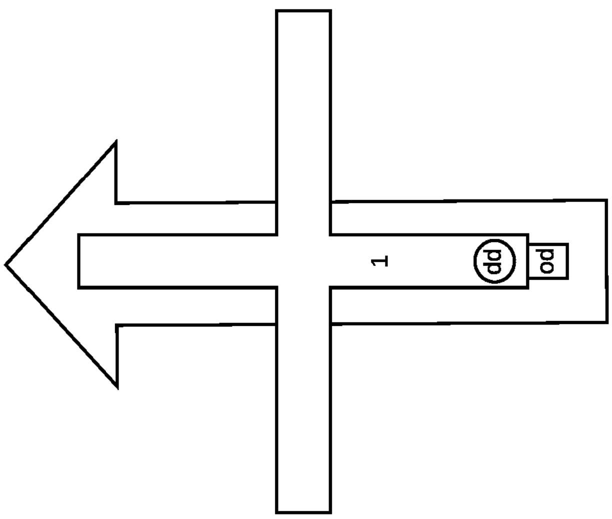

Figure 2 (a)

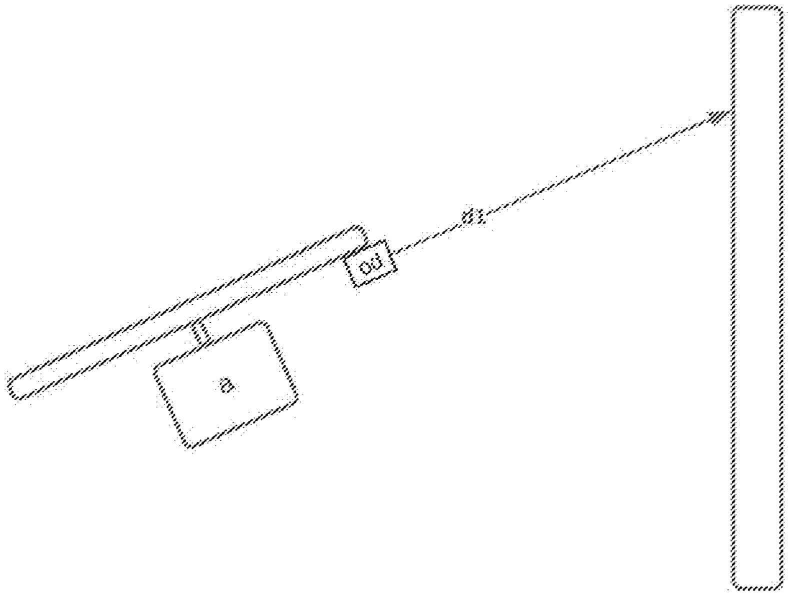

Figure 3 (a)

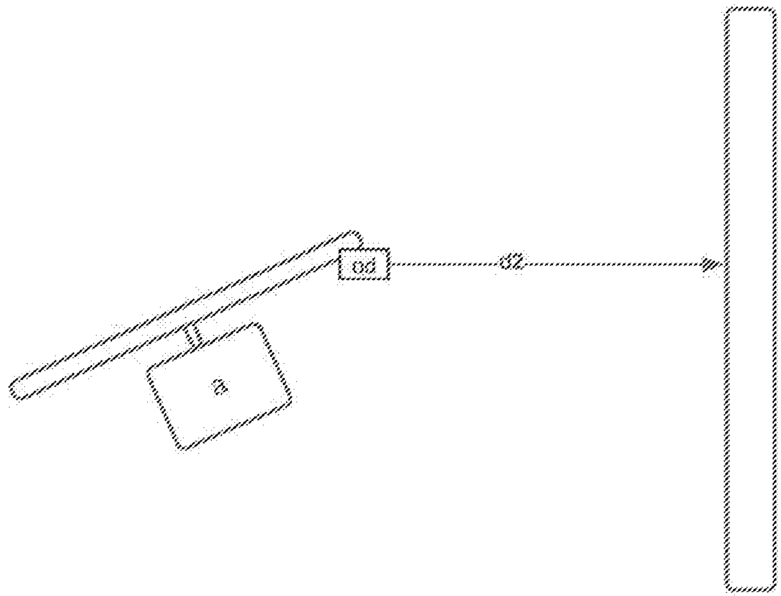

Figure 3 (b)

OBJECT DETECTION SYSTEM

The present invention relates generally to an object detection system and particularly, although not exclusively, to a collision avoidance system for rotorcraft such as helicopters and gyrocopters.

To improve safety it would be desirable for the pilot/crew/controller of manned or unmanned rotorcraft to have a warning of the proximity of the tips of rotary wings/blades to external objects.

According to an aspect of the present invention there is provided a collision avoidance system for a rotorcraft, comprising a proximity detector which is mountable on, or forms part of, a rotary wing.

The system may comprise means for determining the angular position of a rotary wing e.g. the position of blades relative to a helicopter fuselage.

The system may comprise wireless communication means for transmitting information.

Data may be transmitted continuously; alternatively or additionally data may be transmitted periodically.

The transmission of data may be automatic or controlled/triggered by user input. In an example, data can be transmitted using a short-range wireless communications protocol such as: ANT, ANT+, Bluetooth, Bluetooth Low Energy, Cellular, IEEE

802.15.4, IEEE 802.22, ISA100a, Infrared, ISM Band, Near-Field Communications, RFID, 6LoWPAN, Ultra-Wideband, Wi-Fi, Wireless HART, WirelessHD, WirelessUSB, ZigBee, Z-Wave.

A further aspect provides a rotorcraft comprising one or more rotors, each rotor comprising a plurality of rotary wings, in which at least one rotary wing on the or at least one of the rotors is provided with a proximity detector, and in which the rotorcraft further comprising means for determining the angular position of rotary wings.

In some embodiments all rotary wings on a rotor are provided with a tip proximity detector.

The rotorcraft (including compound rotorcraft) may, for example, be a helicopter, a drone (such as a quadcopter) or a gyrocopter.

The rotorcraft may have a single rotor or may have multiple rotors. For example a main rotor for a helicopter (which may also have a tail rotor), or a quadcopter with four rotors.

A further aspect provides a helicopter blade object detection system where a blade mounted detector operating with no physical power or data connection to the main aircraft performs detection of external objects such that this information can be wirelessly communicated to the aircraft.

In aspects and embodiments of the present invention the or each detector may be powered via airflow generated on rotation. Alternatively or additionally onboard power and/or onboard power generation means may be provided.

The detector may determinate external object range therefrom.

Detection may include the determination of external object angular position relative to the aircraft.

The detector may also receive information from the aircraft.

Information communicated to the aircraft may enable audio warnings to be issued.

Information communicated to the aircraft may enable graphical warnings to be issued.

The detector may detect objects located in a different plane to that of the rotating wing/blade.

Detection unit formed in accordance with the present invention may determine Inertial Navigation roll, pitch, yaw data to detect objects located in a different plane to that of the rotating blade.

A further aspect provides a helicopter blade object detection system where blade mounted detection units operating with no physical power or data connection to the main aircraft perform detection of external objects such that this information can be wirelessly communicated to the aircraft.

The detection units may be powered via airflow generated on blade rotation.

Detection may comprise the determination of external object range from the detection unit sensor.

Detection may include the determination of external object angular position relative to the aircraft.

Detection units may also receive information from the aircraft.

The information communicated to the aircraft may enable audio warnings to be issued.

The information communicated to the aircraft may enable graphical warnings to be issued.

The detection unit may detect objects located in a different plane to that of the rotating blade.

The detection unit may determine Inertial Navigation roll, pitch, yaw data to detect objects located in a different plane to that of the rotating blade.

In some aspects and embodiments the present invention proposes the use of a detection unit mounted on each blade to detect the location of external objects.

The unit could, for example, be retro-fitted to existing aircraft as a ‘bolt on’ or built into new rotor blades as part of the production process.

In addition to external object information each detection unit may have knowledge of its angular position relative to the aircraft hull at any time.

Information may be relayed wirelessly back to the cockpit where warnings can be issued to the crew in an audio and or graphical format.

In some embodiments no physical connection is required to the detection unit.

Power may, for example, be supplied via air flow electricity generation.

The angular position of the rotor blade may be detected autonomously via additional downward pointing sensors and a timing mechanism.

The lack of physical connection can provide considerable complexity benefits avoiding needing to relay power and data to / from each blade via the rotor blade drive mechanism.

The system can provide a safety benefit especially useful in training situations. Also, in military situations this could be beneficial where crew are required to fly into confined spaces for surveillance purposes etc. Furthermore, the present invention could, for example, be used to facilitate auto navigation (or be used as part of such a system) of a rotorcraft; for example the possibility of setting a target location with the aircraft manoeuvring around objects autonomously using positional data as input.

Different aspects and embodiments of the invention may be used separately or together.

Further particular and preferred aspects of the present invention are set out in the accompanying independent and dependent claims. Features of the dependent claims may be combined with the features of the independent claims as appropriate, and in combination other than those explicitly set out in the claims. Each aspect can be carried out independently of the other aspects or in combination with one or more of the other aspects.

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

Figure 1 shows the detection unit components;

Figure 2 shows the movement of the blades to explain the determination of the angular position of the external object and

Figure 3 shows the use of directional sensors to obtain a more accurate information.

The example embodiments are described in sufficient detail to enable those of ordinary skill in the art to embody and implement the systems and processes herein described. It is important to understand that embodiments can be provided in many alternative forms and should not be construed as limited to the examples set forth herein.

Accordingly, while embodiments can be modified in various ways and take on various alternative forms, specific embodiments thereof are shown in the drawings and described in detail below as examples. There is no intent to limit to the particular forms disclosed. On the contrary, all modifications, equivalents, and alternatives falling within the scope of the appended claims should be included. Elements of the example embodiments are consistently denoted by the same reference numerals throughout the drawings and detailed description where appropriate.

Unless otherwise defined, all terms (including technical and scientific terms) used herein are to be interpreted as is customary in the art. It will be further understood that terms in common usage should also be interpreted as is customary in the relevant art and not in an idealised or overly formal sense unless expressly so defined herein.

In the following description, all orientational terms, such as upper, lower, radially and axially, are used in relation to the drawings and should not be interpreted as limiting on the invention.

Figures 1 to 3 relate generally to a helicopter blade object detection system. It being understood that the principles described could be equally well applied to other rotorcraft.

In this helicopter blade object detection system individual blades autonomously detect and report external object location information to the aircraft requiring no physical power or data connection to the aircraft.

Detection Unit Components

Figure 1 (a) shows the detection unit components where all components are co-located. The detection unit may be located with sensors at two separate locations – see 'Determination of Blade Angular Position' below.

The detection unit is shown mounted underneath the blade which is a likely deployment in the case of a retro fit to an existing aircraft. However, it may be mounted within the body of the blade which would be more likely in the case of deployment to a new aircraft.

It is may be preferable for the detection unit to be located at the tip of the blade as this will best provide a clear line of sight to the external world.

Electrical power for the unit components is generated as the blades rotate using the airflow turbine generator 'gen'.

A control component ‘ctrl’ determines the range of external objects via the outwards pointing detector (‘od’). It may also make use of a downwards pointing detector (‘dd’) to determine the angular position of the blade at any given time. This is described later with reference to Figure 2. The control unit generates warning events using this information.

Warning events are transmitted wirelessly by the transmitter ‘tr’ to the cockpit to alert the crew. The alert mechanism may be via audio and / or graphical means. In the case of graphical means the angular position and range information would be used to alert the crew to the location of the object like on a traditional radar type display. Range information on its own may be used to provide an audio inclination to indicate object proximity.

The outwards pointing detector ‘od’ is shown in Figure 1 detecting objects in direct line of the blade. However, it may be desirable to use directional sensors to detect objects in some other direction other than direct line. For example, it may be desirable to detect the roll of the helicopter from horizontal and use this information to automatically direct the sensors to detect objects in a generally horizontal direction from the blade tips (which may be in the same horizontal plane as the blades, for example). This is explained in Figure 3 where d2 in Figure 3 (b) is more relevant for collision avoidance than d1 in Figure 3 (a). Use of an Inertial Navigation System (INS) within each detection unit would enable this to be automated. See Figure 1 (b)

It may also be desirable to transmit information from the aircraft to the detection units for example to enable different modes of operation. In this case a detection unit wireless receiver (rec) could be used as shown in Figure 1 (b)

Determination of Blade Angular Position

In Figure 2 (a) as blade 1 passes over the rear hull of the aircraft this is detected by the downwards pointing detector ‘dd’ and within the control unit a timer is started. When the same blade next passes over the rear hull this timer is stopped, and the rotation time determined and saved by the control unit. This process continues with each rotation, so the control unit always has up to date knowledge of the latest time for rotation (T1).

In Figure 2 (b) an object is detected by the outwards pointing detector ‘od’ and range information relayed to the control unit. The control unit knows the timer value at that moment and can use this time value as a proportion of the full rotational time to determine the angular position of the event relative to the hull of the aircraft. In the example shown in Figure 2 the object is detected at T1 / 4 and will therefore be 90 degrees from the hull.

As the aircraft is operated the tilt of the blades may change leading to inaccuracies initiating the timer caused by the downwards pointing detector 'dd' not actually pointing vertically downwards towards the hull. To overcome this the ‘dd’ detector may be located nearer the central hub on the ‘Feathering Hinge’ section of the blade which does not tilt. In this case the whole detection unit may be located here with compensation made for the distance from this location to the blade tip. Alternatively, it may be part located here with the outwards pointing detector ‘od’ located at the blade tip and connected wirelessly to the ‘ctrl’ and ‘dd’ components at the ‘Feathered Hinge’ location – each of the two detector locations having separate power generators as described previously. Alternatively the unit may receive information from the aircraft control systems to relay knowledge of the tilt of the blades as they pass over the hull. This information could be used to compensate for the tilt angle when performing timer calculations.

Although illustrative embodiments of the invention have been disclosed in detail herein, with reference to the accompanying drawings, it is understood that the invention is not limited to the precise embodiments shown and that various changes and modifications can be effected therein by one skilled in the art without departing from the scope of the invention as defined by the appended claims and their equivalents.

CLAIMS

1. A collision avoidance system for a rotorcraft, comprising a proximity detector which is mountable on, or forms part of, a rotary wing.

2. A system as claimed in claim 1, comprising means for determining the angular position of a rotary wing.

3. A system as claimed in claim 1 or claim 2, comprising wireless communication means for transmitting information.

4. A rotorcraft comprising one or more rotors, each rotor comprising a plurality of rotary wings, in which at least one rotary wing on the or at least one of the rotors is provided with a proximity detector, and in which the rotorcraft further comprising means for determining the angular position of rotary wings.

5. A rotorcraft as claimed in claim 4, in which all rotary wings on a rotor are provided with a proximity detector.

6. A rotorcraft as claimed in claim 4 or claim 5, in which the rotorcraft is a helicopter or a gyrocopter.

7. A helicopter blade object detection system where a blade mounted detector operating with no physical power or data connection to the main aircraft

performs detection of external objects such that this information can be wirelessly communicated to the aircraft.

8. A system or rotorcraft according to any preceding claim, in which the or each detector is powered via airflow generated on rotation.

9. A system or rotorcraft according to any preceding claim, in which the detector determinates external object range therefrom.

10. A system or rotorcraft according to any preceding claim, in which detection includes the determination of external object angular position relative to the aircraft.

11. A system or rotorcraft according to any preceding claim, in which the detector also receives information from the aircraft.

12. A system or rotorcraft according to any preceding claim, in which information communicated to the aircraft enables audio warnings to be issued.

13. A system or rotorcraft according to any preceding claim, in which information communicated to the aircraft enables graphical warnings to be issued.

14. A system or rotorcraft according to any preceding claim, in which the detector detects objects located in a different plane to that of the rotating wing/blade.

15. A system or rotorcraft according to claim 14, in which the detection unit determines Inertial Navigation roll, pitch, yaw data to detect objects located in a different plane to that of the rotating blade.

16. An automatic navigation system for a rotorcraft comprising positional sensors provided on or by one or more rotary wings.

17. A system as claimed in claim 16, in which a target location is set, with the rotorcraft manoeuvring around objects autonomously using positional data as input.

Intellectual Property Office

Application No:	GB2100948.5	**Examiner:**	Mr Keir Howe
Claims searched:	1-6, and 8-15 in part	**Date of search:**	20 July 2021

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X,Y	1-7, 9-11-17 Y: 1 at least	US2020/001988 A1 (CRAVENER & SHERRILL) See figure 4 and paragraph [0025] for example, noting proximity sensor 406 may be located on rotorcraft blades.
X,Y	1-7, 9, 11-17 Y: 1 at least	US2020/001979 A1 (CRAVENER et al.) See figure 4 and paragraph [0025] for example, noting proximity sensor 406 may be located on rotorcraft blades.
X,Y	X: 1, 3, 7-9, 11-17 Y: 1 at least	US2014/145025 A1 (FANG & LOZANO) See figure 6 noting sensors in rotor blades, and paragraphs [0014]-[0015] noting sensors are wireless and may harvest power from motion of the blades.
Y	1 at least	KR20130037697 A (RHO) See figure 3 and associated text, noting collision avoidance system proximity sensor 241.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

B64C; B64D

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC

Intellectual Property Office

International Classification:

Subclass	Subgroup	Valid From
B64D	0045/00	01/01/2006
B64C	0027/00	01/01/2006