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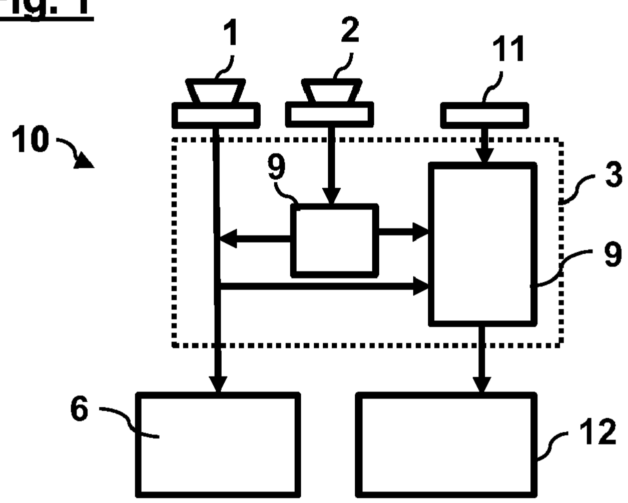
(54) **FIRE DETECTION, LOCALIZATION AND MONITORING SYSTEM AND METHOD FOR A VEHICLE COMPARTMENT**

(57) A fire detection, localization and monitoring system for a vehicle compartment, in particular of an aircraft, comprises a thermal imaging camera configured to provide thermal monitoring data on heat sources within a monitored area of the vehicle compartment; an optical camera configured to provide visual monitoring data of the monitored area; and a system control configured to analyze the thermal monitoring data and to determine temperature hot spots indicating a potential fire within the monitored area based on the analyzed thermal monitoring data, wherein the system control is further configured to provide a visual indication of determined temperature hot spots within the visual monitoring data.

Fig. 1



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Description

[0001] The present invention pertains to a fire detection, localization and monitoring system and method for a vehicle compartment, in particular of an aircraft.

[0002] Aircraft systems for the detection of fire in pressurized compartments of a fuselage typically rely on smoke detectors, which are usually based on optical light scattering technologies. More recent smoke detectors implement smart sensors employing multi-wavelength detection, temperature evaluation and/or humidity assessment.

[0003] However, if the fire source is somehow hidden within the compartment, e.g. behind a lining/ceiling panel, a monument wall or the like, and/or if the fire is still at a very early stage and thus not well detectable, such conventional systems may not be as effective. Thermal imaging cameras could provide an interesting alternative or addition in this regard, as such hidden fires may be detectable by their heat signature. However, thermal images can be difficult to interpret. Moreover, the spatial relationship between a thermal image and the three-dimensional environment of the compartment may be unclear.

[0004] Against this background, it is an object of the present invention to find fast and precise solutions for locating fires in a vehicle compartment independent of smoke development.

[0005] This object is achieved by a fire detection, localization and monitoring system having the features of claim 1, an aircraft having the features of claim 9 and a method having the features of claim 10.

[0006] According to the invention, a fire detection, localization and monitoring system for a vehicle compartment, in particular of an aircraft, comprises a thermal imaging camera configured to provide thermal monitoring data on heat sources within a monitored area of the vehicle compartment; an optical camera configured to provide visual monitoring data of the monitored area; and a system control configured to analyze the thermal monitoring data and to determine temperature hot spots indicating a potential fire within the monitored area based on the analyzed thermal monitoring data, wherein the system control is further configured to provide a visual indication of determined temperature hot spots within the visual monitoring data.

[0007] Further according to the invention, an aircraft comprises a fire detection, localization and monitoring system according to the invention.

[0008] Further according to the invention, a method for fire detection, localization and monitoring in a vehicle compartment, in particular of an aircraft, comprises providing thermal monitoring data on heat sources within a monitored area of the vehicle compartment with a thermal imaging camera; providing visual monitoring data of the monitored area with an optical camera; analyzing the thermal monitoring data and determining temperature hot spots indicating a potential fire within the monitored area based on the analyzed thermal monitoring data with a system control; and providing a visual indication of determined temperature hot spots within the visual monitoring data with the system control.

[0009] Thus, one idea of the present invention is to use the information provided by a thermal imaging camera, in particular infrared imaging data, to detect the source of a hidden fire that may not be immediately detectable in case of more conventional approaches based on smoke detection. As it is known to be difficult to visually extract spatial references from a thermal image and thus to determine based on a thermal image where a dedicated area can be found exactly in the real environment, the present invention accompanies the thermal imaging camera with an optical camera. Any hot spot detected within the thermal images can now be indicated by the system control by means of a corresponding visual indication on the respective images of the optical camera and can thus be localized and monitored within the compartment. To this end, the optical camera monitors substantially the same area as the thermal imaging camera. The visual indication itself may be, for example, a rectangle, circle or other geometric object that is overlayed on the visual images at the corresponding spatial position of the detected hot spot. However, in principle, any other form of highlighting a spatial origin of a fire within a visual image may be used for this purpose. With the help of the present invention, it is possible to locate the source of a fire more quickly and more precisely, even under stress. Thus, remedial actions may be initiated faster and more effectively.

[0010] In some embodiments of the inventions, one or both of the cameras may be permanently installed within the respective vehicle compartment. However, it is to be understood that one or both cameras, as well as the further components of the invention, may also be realized as one or several portable devices.

[0011] Advantageous embodiments and improvements of the present invention are found in the subordinate claims.

[0012] According to an embodiment of the invention, the thermal imaging camera and the optical camera may be configured to provide their respective monitoring data as live video images of the monitored area. The system control may then be configured to lay the visual indication over the live video images of the optical camera.

[0013] Hence, unusual temperature hot spots and potential hidden fires may be spotted in real time, e.g. in a cabin compartment of an aircraft. To this end, the cameras may be positioned at a suitable position anywhere in the compartment where they can monitor at least a certain area of the compartment. It is to be understood that several pairs of cameras may be used to monitor one or several compartments in order to achieve a substantially complete coverage of the respective portions of a vehicle.

[0014] According to an embodiment of the invention, the system control may be communicatively coupled to or integrated in a display configured to display at least the live video images of the optical camera including the overlayed visual indication.

[0015] Such a display may be installed, for example, outside of the respective compartment, e.g. in a control room of the vehicle. For example, a passenger aircraft may comprise one or several displays within the cockpit continuously monitoring the passenger compartment of the aircraft from one or several viewing directions/angles. In this case, the crew can instantly perceive any occurrence of a (potential) hidden fire and/or or can crosscheck fire alarms raised by a conventional smoke detector or other fire detection device.

[0016] According to an embodiment of the invention, the display may be integrated in a mobile device.

[0017] The mobile device may be, for example, a tablet or other portable computer that is carried by the crew of the respective vehicle, by which means the crew can verify potential fires swiftly at any point in time no matter where they are currently positioned within the vehicle. To this end, it is also possible to integrate one or both cameras within the respective mobile device. In this case, the crew can thus move around the compartment and point the device at the respective area of the compartment to be checked for a potentially arising fire.

[0018] According to an embodiment of the invention, the system control may be configured to analyze the thermal monitoring data based on AI and/or machine learning algorithms to detect and localize the temperature hot spots in the thermal monitoring data.

[0019] Such modern data analysis algorithms may localize the exact position of the hidden fire by analyzing the respective thermal (video) images and/or thermal data.

[0020] The processing of these algorithms may then cause the rendering of a label, indicator and/or other visual indication within the visual (video) images of the respective optical camera. The visual (video) images may then be displayed together with the visual indication on a display/monitor in real time.

[0021] According to an embodiment of the invention, the system control may be configured to analyze thermal data of individual pixels within live video images of the thermal imaging camera.

[0022] The person of skill will readily conceive suitable analysis algorithms to extract temperature hot spots from the thermal imaging data. For example, one or several temperature thresholds may be used in order to define a temperature hot spot and corresponding alarming temperature characteristics. Such thresholds may be defined for individual pixels or groups of pixels.

[0023] According to an embodiment of the invention, the system control may be configured to evaluate a criticality of each determined hot spot based on vehicle configuration data characterizing sensitive vehicle systems and/or sensitive cargo within the monitored area.

[0024] For example, critical vehicle systems, electric systems and/or wiring or the like installed at or close to the temperature hot spot and thus the potential fire could be taken into account in this embodiment. The system control may then be able to assess how critical the temperature development is at the respective position and whether certain systems and/or components may need to be switched off and/or shut down to facilitate adequate remedial procedures. In a similar vein, sensible cargo present at or near the respective temperature hot spot may be considered for the further procedure.

[0025] To this end, the system control may also be configured to employ AI and/or machine learning algorithms that take into account the further vehicle configuration data.

[0026] According to an embodiment of the invention, the system control may be configured to transmit information about the determined temperature hot spots to a remote entity.

[0027] For example, data such a position and affected systems/cargo could be transmitted remotely to a control station, a ground station or the like. In that vein, firefighting measures could be immediately started as soon as an affected aircraft is back down on the ground.

[0028] The invention will be explained in greater detail with reference to exemplary embodiments depicted in the drawings as appended.

[0029] The accompanying drawings are included to provide a further understanding of the present invention and are incorporated in and constitute a part of this specification. The drawings illustrate the embodiments of the present invention and together with the description serve to explain the principles of the invention. Other embodiments of the present invention and many of the intended advantages of the present invention will be readily appreciated as they become better understood by reference to the following detailed description. The elements of the drawings are not necessarily to scale relative to each other. In the figures, like reference numerals denote like or functionally like components, unless indicated otherwise.

[0030] Fig. 1 shows a schematic view of a fire detection, localization and monitoring system according to an embodiment of the invention.

[0031] Fig. 2 schematically depicts a flow diagram of a fire detection, localization and monitoring method using the system of Fig. 1.

[0032] Fig. 3 is a schematic depiction of thermal and visual monitoring data employed by the system and method of Figs. 1 and 2.

[0033] Fig. 4 is a front view of a mobile device implementing the system and method of Figs. 1 and 2.

[0034] Fig. 5 is a passenger aircraft equipped with the system of Fig.1.

[0035] Although specific embodiments are illustrated and described herein, it will be appreciated by those of ordinary skill in the art that a variety of alternate and/or equivalent implementations may be substituted for the specific embodiments shown and described without departing from the scope of the present invention. Generally, this application is intended to cover any adaptations or variations of the specific embodiments discussed herein.

[0036] Figure 1 shows a schematic view of a fire detection, localization and monitoring system 10 according to an embodiment of the invention. Fig. 2 depicts the steps of a corresponding method M.

[0037] The fire detection, localization and monitoring system 10 is provided to monitor a vehicle compartment, e.g. a passenger cabin of a passenger aircraft 100 as exemplarily depicted in Fig. 5, in order to determine potential fires that may (still) be hidden for normal smoke detectors and other conventional fire detection means.

[0038] To this end, the present system 10 provides two cameras 1, 2: a thermal imaging camera 1 configured to provide thermal monitoring data 1a on heat sources within a monitored area 5 of the vehicle compartment and an optical camera 2 configured to provide visual monitoring data 2a of the monitored area 5. Both cameras 1, 2 are configured to provide their respective monitoring data 1a, 2a as live video images of the monitored area 5. The thermal imaging camera 1 is provided to detect sources of hidden fires within the monitored area. The optical camera 2 on the other hand is provided to visualize the actual position of the hidden fire within the compartment in a vein that can be comprehended by the crew.

[0039] To accomplish this, the system 10 further comprises a system control 3 configured to analyze the thermal monitoring data 1a and to determine temperature hot spots 4 indicating a potential fire within the monitored area 5 based on the analyzed thermal monitoring data 1a. The system control 3 is then configured to provide a visual indication 6 of determined temperature hot spots 4 within the visual monitoring data 2a.

[0040] An example for this is shown in Fig. 3. Here, a temperature hot spot 4 is detected within the video feed of the thermal monitoring data 1a, e.g. at the ceiling of a passenger cabin (left of Fig. 3). The system control 3 now highlights the corresponding position in the compartment as a visual indication 6 within the video feed of the visual monitoring data 2a, e.g. as a highlighted and/or colored and/or blinking rectangle around the actual position of the temperature hotspot 4 within the visual image (right side of Fig. 3).

[0041] The method M of Fig. 2 thus correspondingly comprises under M1 providing thermal monitoring data 1a on heat sources within a monitored area 5 of the vehicle compartment with the thermal imaging camera 1. The method M further comprises under M2 providing visual monitoring data 2a of the monitored area 5 with the optical camera 2. The method M further comprises under M3 analyzing the thermal monitoring data 1a and determining temperature hot spots 4 indicating a potential fire within the monitored area 5 based on the analyzed thermal monitoring 1a data with the system control 3. The method M finally comprises under M4 providing a visual indication 6 of determined temperature hot spots 4 within the visual monitoring data 2a with the system control 3.

[0042] The system control 3 may be configured to analyze the thermal monitoring data 1a based on AI and/or machine learning algorithms 9 to detect and localize the temperature hot spots 4 in the thermal monitoring data 1a. This can be done, for example, by running such advanced algorithms on the thermal video images themselves and/or the thermal data of the individual pixels of each such image.

[0043] The system control 3 may further be configured to evaluate a criticality of each determined hot spot 4 based on vehicle configuration data 11 characterizing sensitive vehicle systems and/or sensitive cargo within the monitored area. Also in this case the system control 3 may rely on AI and/or machine learning tools in order to extract and evaluate any relevant information (cf. Fig. 1).

[0044] The analysis results may not only be used to provide the visual indication 6 within the visual monitoring data 2a. In addition, the system control 3 may transmit information about the determined temperature hot spots 4 and/or the assessed criticality as well as the affected vehicle systems and/or cargo to a remote entity 12, e.g. a ground station (cf. Fig. 1). In this case, any necessary remedial procedures may be swiftly and effectively prepared on board of the aircraft as well as on the ground.

[0045] The cameras 1, 2 may be installed within the vehicle compartment for the present purpose in a suitable position with a good field of view on any relevant portions of the compartment. The system control 2 may then be communicatively coupled to and/or integrated in a display 7 to display at least the live video images of the optical camera 2 including the overlayed visual indication 6.

[0046] Such a display 7 may, for example, be installed within a cockpit of the aircraft 100. Alternatively, or additionally, the display 7 may also be integrated in a mobile device 8, e.g. a tablet or another handheld crew device. An example for such a device 8 is shown in Fig. 4.

[0047] In case of such a mobile device 8, also one or both of the cameras 1, 2 may in principle be integrated in the device 8. In this case, a member of the crew may walk around the compartment and point the respective device 8 at various portions of the compartment in order to check for potential hidden fires and receive feedback on any detected hot spot.

[0048] In the foregoing detailed description, various features are grouped together in one or more examples or examples with the purpose of streamlining the disclosure. It is to be understood that the above description is intended to be illustrative, and not restrictive. It is intended to cover all alternatives, modifications and equivalents. Many other examples will be apparent to one skilled in the art upon reviewing the above specification. The embodiments were chosen and described in order to best explain the principles of the invention and its practical applications, to thereby enable others skilled in the art to best utilize the invention and various embodiments with various modifications as are suited to the particular use contemplated.

List of reference signs

[0049]

1	thermal imaging camera
1a	thermal monitoring data
2	optical camera
2a	visual monitoring data
3	system control
4	temperature hot spot
5	monitored area
6	visual indication
7	display
8	mobile device
9	AI and/or machine learning algorithm
10	fire detection, localization and monitoring system
11	vehicle configuration data
12	remote entity
100	aircraft
M	method
M1-M4	method steps

Claims

1. Fire detection, localization and monitoring system (10) for a vehicle compartment, in particular of an aircraft (100), comprising:

   a thermal imaging camera (1) configured to provide thermal monitoring data (1a) on heat sources within a monitored area (5) of the vehicle compartment;
   an optical camera (2) configured to provide visual monitoring data (2a) of the monitored area (5); and
   a system control (3) configured to analyze the thermal monitoring data (1a) and to determine temperature hot spots (4) indicating a potential fire within the monitored area (5) based on the analyzed thermal monitoring data (1a), wherein the system control (3) is further configured to provide a visual indication (6) of determined temperature hot spots (4) within the visual monitoring data (2a).

2. Fire detection, localization and monitoring system (10) according to claim 1, wherein the thermal imaging camera (1) and the optical camera (2) are configured to provide their respective monitoring data (1a, 2a) as live video images of the monitored area (5), wherein the system control (3) is configured to lay the visual indication (6) over the live video images of the optical camera (2).

3. Fire detection, localization and monitoring system (10) according to claim 2, wherein the system control (3) is communicatively coupled to or integrated in a display (7) configured to display at least the live video images of the optical camera (2) including the overlayed visual indication (6).

4. Fire detection, localization and monitoring system (10) according to claim 3, wherein the display (7) is integrated in a mobile device (8).

5. Fire detection, localization and monitoring system (10) according to one of the claims 1 to 4, wherein the system control (3) is configured to analyze the thermal monitoring data (1a) based on AI and/or machine learning algorithms (9) to detect and localize the temperature hot spots (4) in the thermal monitoring data (1a).

6. Fire detection, localization and monitoring system (10) according to one of the claims 1 to 5, wherein the system control (3) is configured to analyze thermal data of individual pixels within live video images of the thermal imaging camera (1).

7. Fire detection, localization and monitoring system (10) according to one of the claims 1 to 6, wherein the system control (3) is configured to evaluate a criticality of each determined hot spot (4) based on vehicle configuration data (11) characterizing at least one of sensitive vehicle systems and sensitive cargo within the monitored area (5).

8. Fire detection, localization and monitoring system (10) according to one of the claims 1 to 7, wherein the system control (3) is configured to transmit information about the determined temperature hot spots (4) to a remote entity (12).

9. Aircraft (100) having a fire detection, localization and monitoring system (10) according to one of the claims 1 to 8.

10. Method (M) for fire detection, localization and monitoring in a vehicle compartment, in particular of an aircraft (100), comprising:

    providing (M1) thermal monitoring data (1a) on heat sources within a monitored area (5) of the vehicle compartment with a thermal imaging camera (1);
    providing (M2) visual monitoring data (2a) of the monitored area (5) with an optical camera (2);
    analyzing (M3) the thermal monitoring data (1a) and determining temperature hot spots (4) indicating a potential fire within the monitored area (5) based on the analyzed thermal monitoring (1a) data with a system control (3); and
    providing (M4) a visual indication (6) of determined temperature hot spots (4) within the visual

monitoring data (2a) with the system control (3).

11. Method (M) according to claim 10, wherein the respective monitoring data (1a, 2a) are provided as live video images of the monitored area (5), wherein the visual indication (6) is laid over the live video images of the optical camera (2), wherein at least the live video images of the optical camera (2) including the overlayed visual indication (6) are displayed on a display (7).

12. Method (M) according to claim 10 or 11, wherein the thermal monitoring data (1a) are analyzed by the system control (3) based on AI and/or machine learning algorithms (9) to detect and localize the temperature hot spots (4) in the thermal monitoring data (1a).

13. Method (M) according to one of the claims 10 to 12, wherein thermal data of individual pixels within live video images of the thermal imaging camera (2) are analyzed by the system control (3).

14. Method (M) according to one of the claims 10 to 13, wherein a criticality of each determined hot spot (4) is evaluated by the system control (3) based on vehicle configuration data (11) characterizing at least one of sensitive vehicle systems and sensitive cargo within the monitored area (5).

15. Method (M) according to one of the claims 10 to 14, wherein information about the determined temperature hot spots (4) are transmitted by the system control (3) to a remote entity (12).

Fig. 1

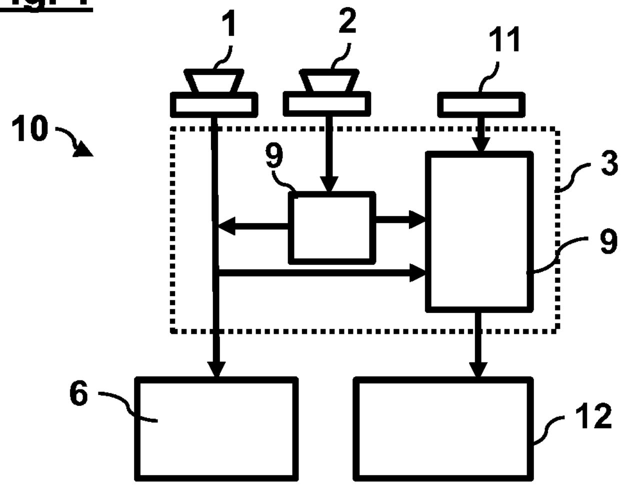


Fig. 2

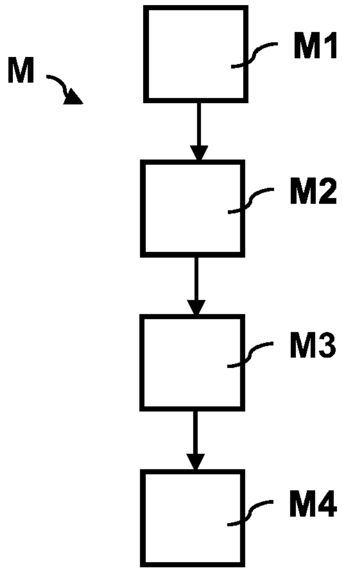


Fig. 3

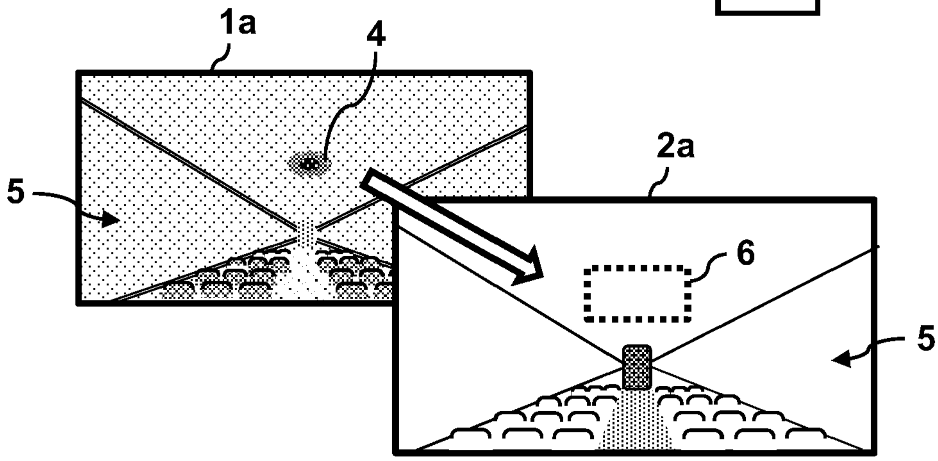


Fig. 4

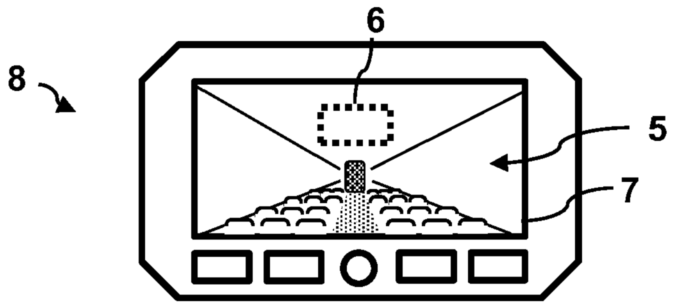
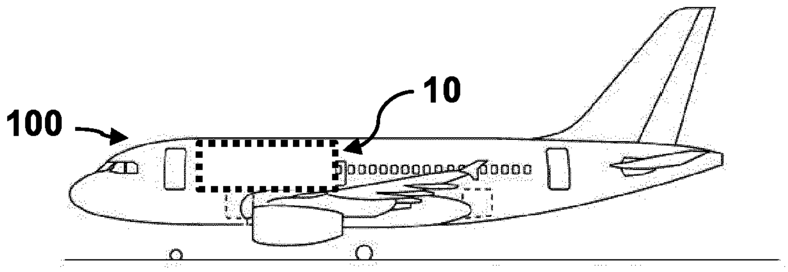


Fig. 5



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EUROPEAN SEARCH REPORT

Application Number
EP 22 16 9792

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2003/215141 A1 (ZAKRZEWSKI RADOSLAW ROMUALD [US] ET AL) 20 November 2003 (2003-11-20) * paragraphs [0002], [0004], [0009], [0010], [0039] - [0041], [0043] - [0044], [0052], [0055] - [0058], [0061], [0062], [0066], [0067], [0076] - [0077], [0080] * * paragraphs [0091] - [0094], [0102], [0105], [0106], [0136], [0147] - [0149], [0151] - [0153], [0204], [0205], [0302] * -----	1-15	INV. G08B17/12 G08B5/36 A62C3/08
X	KRULL ET AL: "Design and test methods for a video-based cargo fire verification system for commercial aircraft", FIRE SAFETY JOURNAL, ELSEVIER, AMSTERDAM, NL, vol. 41, no. 4, 1 June 2006 (2006-06-01), pages 290-300, XP005433973, ISSN: 0379-7112, DOI: 10.1016/J.FIRESAF.2005.07.009 * abstract * * Sections 1, 2, 3, 4, 6, 12; figures 1-3 * -----	1-7,9-14	

TECHNICAL FIELDS SEARCHED (IPC)
G08B
A62C

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	19 October 2022	Russo, Michela

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2003215141 A1	20-11-2003	US 2003215141 A1	20-11-2003
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