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AUTOMATED RUNWAY OCCUPIED ALERT

Abstract

A method for providing an automated runway occupied alert comprises receiving, from a location sensor on board an aircraft, location sensor data for the aircraft. Location data is received for target traffic. Based on the location sensor data for the aircraft, a location, a speed, and a direction of travel are determined for the aircraft. Based on the location data for the target traffic, a location, a speed, and a direction of travel are determined for the target traffic. The method further comprises determining that the aircraft meets one or more runway occupancy criteria, and determining that the target traffic meets the one or more runway occupancy criteria. The runway occupied alert is output based upon determining that the aircraft and the target traffic meet the one or more runway occupancy criteria.

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Background/Summary

BACKGROUND

[0001] Air traffic controllers, ground controllers, pilots, and airport ground vehicle operators monitor movements of aircraft and ground vehicles to ensure safe and efficient aviation operations. Traffic monitoring can include visual tracking, as well as radar or satellite-based systems to monitor the aircraft and ground vehicles. In this manner, air traffic controllers, ground controllers, pilots, and vehicle operators can coordinate movements of the aircraft and ground vehicles to avoid conflicts during airport operations.

SUMMARY

[0002] According to one aspect of the present disclosure, a method is provided for providing an automated runway occupied alert. The method comprises receiving, from a location sensor on board an aircraft, location sensor data for the aircraft. Location data is also received for target traffic. Based on the location sensor data for the aircraft, a location, a speed, and a direction of travel are determined for the aircraft. A location, a speed, and a direction of travel are determined for the target traffic based on the location data for the target traffic. The method further comprises determining, based at least on the location sensor data for the aircraft, that the aircraft meets one or more runway occupancy criteria, and determining, based on the location data for the target traffic, that the target traffic meets the one or more runway occupancy criteria. The runway occupied alert is output based upon determining that the aircraft and the target traffic meet the one or more runway occupancy criteria.

[0003] This simplified summary of the specification is presented to provide a basic understanding of some aspects of the specification. This summary is not an extensive overview of the specification. It is intended to neither identify key or critical elements of the specification nor delineate any particular embodiments of the specification, or any scope of the claims. Its sole purpose is to present some concepts of the specification in a simplified form as a prelude to the more detailed description that is presented in this disclosure.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIG. **1** shows a block diagram of an example system for providing an automated runway occupied alert.

[0005] FIG. **2** shows a schematic example of an operating environment including an aircraft.

[0006] FIG. **3** schematically illustrates an example of a tablet computing device with a graphical user interface (GUI) that can be used by an aircraft operator.

[0007] FIG. **4** shows another schematic example of the operating environment of FIG. **2**.

[0008] FIG. **5** schematically illustrates the tablet computing device of FIG. **3** configured to output a runway occupied alert.

[0009] FIGS. **6**A-**6**B show a block diagram of an example method for providing a runway occupied alert.

[0010] FIG. **7** shows a block diagram of an example computing system.

DETAILED DESCRIPTION

[0011] As introduced above, air traffic controllers, ground controllers, pilots, and other vehicle operators can coordinate movements of the aircraft and ground vehicles to avoid conflicts during airport operations. However, in some instances, an aircraft or a ground vehicle can unexpectedly or erroneously enter a runway. For example, a pilot can inadvertently enter an active runway without clearance, or the pilot may be given clearance to use the runway by mistake. This is generally referred to as a runway incursion. Runway incursions represent a serious safety risk, as they can lead to collisions.

[0012] Radar can be used by air traffic control and ground control to monitor locations of aircraft

on the ground and/or in the air to prevent runway incursions. However, radar can have blind spots. It can also be challenging to use radar to track aircraft or vehicles on the ground.
[0013] Visual observation is another technique that can prevent runway incursions and avoid collisions. Runway markers and lighting patterns also distinguish different areas of an airport (e.g., runways and taxiways) and vehicles. However, visual observation can be difficult in adverse weather and other low-visibility conditions. Furthermore, verbal reporting and communication of traffic positions can be less reliable than an automated alerting system. For example, miscommunication can potentially lead to hazardous situations. Furthermore, delayed instructions may not provide sufficiently advanced notice for an aircraft to clear a runway.
[0014] To address the above issues, examples are disclosed that relate to providing an automated runway occupied alert. Briefly, location sensor data for an aircraft is received from a location sensor on board the aircraft. Location data is also received for target traffic. A location, a speed, and a direction of travel are determined for the aircraft and the target traffic based upon the location sensor data for the aircraft and the location data for the target traffic, respectively. The runway occupied alert is output based upon determining that the aircraft and the target traffic meet one or more runway occupancy criteria.
[0015] Alerting pilots about the location and movements of other aircraft and ground vehicles allows pilots to take precautions to ensure the safety of their passengers and equipment. This system has the potential to greatly reduce the risk of runway incursions, for example at busy airports that deal with a high volume of traffic, or during inclement meteorological conditions that prevent visual identification of traffic.
[0016] FIG. **1** shows an example of a system **100** for providing a runway occupied alert. The system **100** includes a computing system **102**. The computing system **102** comprises a processor and a memory storing instructions executable by the processor. The instructions are executable to implement the methods and processes described herein. Additional aspects of the computing system **102** are described in more detail below with reference to FIG. **7**.
[0017] In some examples, the computing system **102** comprises a tablet computing device, a laptop computing device, a mobile computing device (e.g., a smartphone), or a wearable computing device (e.g., a smartwatch) that is operated by an end user **104** (e.g., an aircraft pilot or another vehicle operator). For example, at least a portion of the computing system **102** can be implemented at a tablet computing device **106** operated by the end user **104**. In other examples, the computing system **102** comprises a server computing device. For example, aspects of the methods and processes described herein can be implemented at a server computing device executing a web application that is operated by the end user **104** through a user computing device such as tablet computing device **106**. In this manner, at least a portion of the computing system **102** can be implemented on board an aircraft and/or a ground vehicle. For example, FIG. **2** shows an example of an aircraft **224** in which a computing device, such as the computing system **102** of FIG. **1**, can be located.
[0018] As introduced above, the computing system **102** can take the form of a user computing device, such as the tablet computing device **106** of FIG. **1**, rather than a computing system integrated with an aircraft's avionics equipment. By providing the computing system separately from the avionics, the computing system may output notifications to an aircraft operator other than those generally included in integrated avionics according to aeronautical regulations (e.g., Federal Aviation Administration regulations and notices). It will also be appreciated that, where permissible, one or more aspects of the computing system can be integrated into an aircraft and/or a ground vehicle (e.g., as part of a glass cockpit system or other avionics equipment).
[0019] Referring again to FIG. **1**, the computing system **102** is configured to receive, from a location sensor **108** on board an aircraft, location sensor data **110** for the aircraft. In some examples, the location sensor data **110** are obtained from a sensor coupled to the aircraft. For example, a tablet computing device on board the aircraft can obtain the location sensor data from a

location sensor integrated with the aircraft. In other examples, the tablet computing device can include one or more integrated location sensors configured to provide location sensor data for the tablet computing device. When the tablet computing device is on-board the aircraft, such location sensor data can be substituted for, or augment, data obtained from aircraft systems.

[0020] In some examples, the location sensor **108** comprises a GPS sensor **112** and the location sensor data **110** comprises GPS data **114** from the GPS sensor **112**. The location sensor can additionally or alternatively comprise an accelerometer **116** (e.g., as one or more components of an inertial measurement unit or IMU). The location sensor data **110** can comprise accelerometer data **118** from the accelerometer **116**.

[0021] The computing system **102** is further configured to receive location data **120** for target traffic. FIG. **2** shows an example of target traffic in the form of a second aircraft **202**. It will also be appreciated that the target traffic can comprise any other suitable type of traffic, such as a ground vehicle. In some examples, the location data **120** for the target traffic comprises automatic dependent surveillance-broadcast (ADS-B) data **122** received from an ADS-B receiver **124** communicatively coupled with the computing system **102**. In some examples, the ADS-B receiver **124** is integrated with the aircraft (e.g., as an antenna located on an exterior surface of a fuselage of the aircraft). In other examples, the ADS-B receiver **124** is a peripheral ADS-B receiver device that can be coupled to a computing system, such as the tablet computing device **106** of FIG. **1**. The ADS-B receiver **124** is configured to receive an altitude and position of the target traffic according to ADS-B Out equipment performance standards (e.g., 14 CFR 91.227).

[0022] In other examples, the location data **120** for the target traffic comprises flight alarm data **148** received from the target traffic. For example, the target traffic can include a flight data transmitter **150**. The flight data transmitter **150** is configured to transmit the location data **120** from the target traffic to the computing system **102**. For example, the flight data transmitter **150** can transmit GPS data, barometric pressure data, etc., which can alert the computing system **100** and other traffic in the vicinity of the target traffic if the target traffic represents a potential conflict.

[0023] The computing system **102** is configured to determine a location **126**, a speed **128** (e.g., a ground speed or an air speed), and a direction of travel **130** for the aircraft based on the location sensor data **110** for the aircraft. In some examples, the location **126**, the speed **128**, and the direction of travel **130** are output to an operator of the aircraft. For example, the location **126**, the speed **128**, and the direction of travel **130** can be output for display to the end user **104**.

[0024] FIG. **3** shows an example of a tablet computing device **302** that can be used by an aircraft operator. The tablet computing device **302** comprises a display **304** configured to display a plurality of graphical user interface (GUI) elements. The GUI elements include an altimeter **306**, an airspeed indicator **308**, a heading indicator **310**, and a course deviation indicator **312**. These elements are arranged around a simulated attitude indicator **314** for an aircraft.

[0025] In some examples, the computing system **102** of FIG. **1** comprises map data **132**. The map data **132** can additionally or alternatively be output for display to the end user **104** via the tablet computing device **106**. In the example of FIG. **3**, map data **316** is displayed on the tablet computing device **302** in the form of an instrument approach procedure plate. In other examples, any other suitable map data can be provided. Other examples of suitable map data include an airport ground diagram, a sectional chart, a helicopter chart, an enroute chart, and a departure procedure plate.

[0026] Referring again to FIG. **1**, the computing system **102** is also configured to determine a location **134**, a speed **136**, and a direction of travel **138** for the target traffic based on the location data **120** for the target traffic. However, information about the target traffic may not be output without determining that the location **134**, the speed **136**, and the direction of travel **138** of the target traffic and that the location **126**, the speed **128**, and the direction of travel **130** each satisfy one or more runway occupancy criteria **140**, as indicated at **144** in FIG. **1**. Suppression of outputs regarding the target traffic can prevent distracting aircraft operators and/or other vehicle operators.

[0027] The following paragraphs describe examples of runway occupancy criteria **140**. In some examples, the one or more runway occupancy criteria **140** include determining that the map data **132** includes the following criteria for a runway the aircraft is on or approaching: a base latitude, a base longitude, a base heading (e.g., as a true heading), a reciprocal latitude for the opposite runway threshold, a reciprocal latitude for the opposite runway threshold, and a reciprocal heading (e.g., the heading of the opposite runway).

[0028] In some examples, the one or more runway occupancy criteria **140** additionally or alternatively include determining, based at least on the location of the target traffic, that the target traffic is on a runway. For example, and with reference now to FIG. **4**, to determine if the aircraft **202** and/or the aircraft **224** is on the runway **212**, a linestring rectangle **226** can be created using the latitude and longitude of each end of the runway **212**, as well as a published width of the runway **212**. In cases where width is not present for a runway, a default width value can be used. In some examples, the default width comprises a width in a range of 10-200 feet. In some more specific examples, the default width comprises a width in a range of 25-100 feet. In further, more specific examples, the default width comprises a width in a range of 50-75 feet. These boundaries help the computing system differentiate whether the aircraft and/or the target traffic is on the runway or adjacent to the runway (e.g., holding short of the runway or exiting the runway).

[0029] Parallel runways (e.g., runways **212** and **222** of FIG. **2**) can have centerlines that are close enough together to make it challenging to distinguish each runway. To prevent alerting pilots of aircraft in a vicinity of one or more adjacent runways, the output of the runway occupied alert can be inhibited for parallel runways in which a distance between a centerline of each runway is less than a threshold distance. In some examples, the threshold distance comprises a distance in a range of 0-2500 feet. In some more specific examples, the threshold distance comprises a distance in a range of 0-1000 feet. In further, more specific examples, the threshold distance comprises a distance in a range of 0-850 feet.

[0030] In some examples, the one or more runway occupancy criteria **140** include determining that the location data **120** for the target traffic is not sourced from the internet. Internet traffic information can be delayed (e.g., due to network latency), which can result in inaccurate alerts. For example, the internet traffic information can indicate that an aircraft is on final when it has already arrived at the airport in the real world. In contrast, the use of location data that is closer to real time can provide a more accurate picture of traffic conditions.

[0031] Additionally or alternatively, in some examples, the one or more runway occupancy criteria **140** include determining that the target traffic is grounded. For example, the aircraft **202** of FIG. **2** is grounded on the runway **212**, and the aircraft **224** is also grounded on the runway **212**. By ensuring that the target traffic is not airborne, the computing system may not erroneously alert pilot(s) due to proximity of airborne traffic (e.g., an aircraft overflying the runway **212**).

[0032] In some examples, the one or more runway occupancy criteria **140** additionally or alternatively include determining that the aircraft and/or the target traffic is at or within a threshold distance to a runway threshold. FIG. **2** shows an example of a threshold distance **216** with respect to a ground vehicle **204**. In some examples, the threshold distance **216** is a direct distance metric. For example, the threshold distance **216** can correspond to a distance between the runway **212** and a hold-short line **218**. In some examples, the threshold distance **216** is in the range of 0-300 feet. In some more specific examples, the threshold distance **216** is in a range of 50-300 feet. In further, more specific examples, the threshold distance **216** is in a range of 100-200 feet. The threshold distance can be selected to prevent prematurely alerting the pilot(s).

[0033] Additionally or alternatively, in some examples, the one or more runway occupancy criteria **140** of FIG. **1** include determining that the aircraft does not qualify for more than one runway. For example, and with reference again to FIG. **2**, an alert will not be output if the aircraft **202** satisfies the one or more runway occupancy criteria for the runway **212** and a second runway **222**. In this manner, the runway occupancy criteria prevent the computing system from outputting an inaccurate alert if it cannot reliably discern which runway the aircraft is on.

[0034] In some examples, the one or more runway occupancy criteria **140** additionally or alternatively include determining that the target traffic is not diverging from the aircraft. Divergence can be established based at least upon the target traffic having a greater ground speed than an ownship aircraft, and also having a heading in another direction from the ownship aircraft (e.g., traveling away from the ownship aircraft). Traffic diverging from the ownship aircraft's position may not trigger the runway occupied alert. In contrast, traffic that is not diverging, or that is converging on the ownship aircraft, may trigger the runway occupied alert. For example, the runway occupied alert may not be triggered if the aircraft **202** is taking off in a direction of the runway **212** and has a greater ground speed than the aircraft **224**. However, if the aircraft **224** is not diverging from the other aircraft **202**, a runway occupied alert **228** can be output to pilots of the aircraft **224**. In this manner, the pilots can judge whether the other aircraft **202** is a risk to their ground position and can respond accordingly.
[0035] As introduced above, based upon determining that the aircraft and the target traffic meet the one or more runway occupancy criteria, the computing system **102** of FIG. **1** is configured to output a runway occupied alert **146**. FIG. **5** shows various forms of a runway occupied alert that can be output by the tablet computing device **302** of FIG. **3**. In some examples, the runway occupied alert includes a visual notification **318** on the display **304**. In the example of FIG. **6**, the visual notification **318** takes the form of text “RUNWAY OCCUPIED” superimposed over the attitude indicator **314**. In other examples, the visual notification **318** can have any other suitable form (e.g., different text or a color change on the display **304**). The runway occupied alert can additionally or alternatively include any other suitable information. For example, the runway occupied alert can include the runway number and airport identifier (e.g., KSEA or KPDX).
[0036] The runway occupied alert additionally or alternatively includes an audible notification **320**. In the example of FIG. **6**, the audible notification **320** comprises a verbal output saying “runway occupied.” In other examples, the audible notification **320** can have any other suitable form (e.g., an alarm or other suitable sound).
[0037] The runway occupied alert additionally or alternatively includes haptic feedback. For example, the tablet computing device **302** can vibrate, as indicated at **322**A and **322**B in FIG. **6**. The tablet computing device **302** can additionally or alternatively transmit an instruction to cause a wearable computing device, such as a smartwatch worn by a vehicle operator, to vibrate. In this manner, the tablet computing device **302** can alert pilot(s) and/or other vehicle operators of other traffic on the runway.
[0038] In some examples, and with reference again to FIG. **1**, the runway occupied alert **146** can be repeated and/or remain active for a threshold time. In some examples, the runway occupied alert **146** can be output once per minute or at any other suitable rate. The runway occupied alert **146** can additionally or alternatively be dismissed by a user (e.g., by tapping the display **304** of the tablet computing device **302** of FIG. **6**). In some examples, the runway occupied alert **146** is dismissed when one or more of the runway occupied criteria **140** are no longer satisfied. For example, the computing system **102** can cease output of the runway occupied alert **146** if the aircraft leaves the runway.
[0039] FIGS. **6**A-**6**B show a flow diagram depicting an example method **600** for providing an automated runway occupied alert. The following description of the method **600** is provided with reference to FIGS. **1-5** above and FIG. **7** below. It will be appreciated that the method **600** also can be performed in other contexts.
[0040] Referring first to FIG. **6**A, at **602**, the method **600** comprises receiving, from a location sensor on board an aircraft, location sensor data for the aircraft. In some examples, at **604**, receiving the location sensor data for the aircraft comprises receiving one or more of GPS data from a GPS sensor or accelerometer data from an accelerometer on board the aircraft.
[0041] At **606**, the method **600** comprises receiving location data for target traffic. As indicated at **608**, in some examples, the target traffic comprises one or more of another aircraft or a ground

vehicle. For example, FIG. **2** shows an example of target traffic in the form of an aircraft **202**. At **610**, in some examples, receiving the location data for the target traffic comprises receiving ADS-B data from an ADS-B receiver communicatively coupled with the computing system, and using the ADS-B data to determine a location of the target traffic. ADS-B can provide location data that is more accurate and timely than location data obtained from other sources, such as the internet.
[0042] The method **600** further comprises, at **612**, based on the location sensor data for the aircraft, determining a location, a speed, and a direction of travel for the aircraft. At **614**, the method **600** further comprises, based on the location data for the target traffic, determining a location, a speed, and a direction of travel for the target traffic. In this manner, the location sensor data for the aircraft and the location data for the target traffic can be used to identify potential traffic conflicts.
[0043] Referring now to FIG. **6**B, at **616**, the method **600** further comprises, at **616**, determining that the aircraft and the target traffic meet the one or more runway occupancy criteria. Steps **618-626** describe examples of runway occupancy criteria.
[0044] In some examples, at **618**, determining that the aircraft meets the one or more runway occupancy criteria or determining that the target traffic meets the one or more runway occupancy criteria comprises determining that the aircraft or the target traffic, respectively, is at or within a threshold distance to a runway threshold. For example, FIG. **2** shows a threshold distance **216** with respect to the ground vehicle **204** and the runway **212**. The threshold distance can be selected to avoid providing a premature alert to a vehicle operator that is not yet within the threshold distance of the runway.
[0045] At **620**, in some examples, one or more of determining that the aircraft meets the one or more runway occupancy criteria or determining that the target traffic meets the one or more runway occupancy criteria comprises determining that the aircraft or the target traffic, respectively, does not qualify for more than one runway. For example, a runway incursion alert will not be output if an aircraft or other traffic satisfies one or more runway occupancy criteria for two parallel runways. In this manner, the runway occupancy criteria prevent output of an inaccurate alert if it is unclear which runway (if any) the aircraft or the target traffic is on.
[0046] In some examples, at **622**, determining that the target traffic meets the one or more runway occupancy criteria comprises determining that the target traffic is grounded. For example, the aircraft **202** of FIG. **2** is grounded on the runway **212**. In this manner, the runway occupancy criteria prevent output of an inaccurate alert in response to an aircraft on departure or overflying the runway.
[0047] At **624**, in some examples, determining that the target traffic meets the one or more runway occupancy criteria comprises determining that the target traffic is not diverging from the aircraft. For example, the aircraft **224** of FIG. **2** may not receive the runway occupancy alert if the aircraft **202** is taking off in a direction of the runway **212** and has a greater ground speed than the aircraft **224**. In this manner, pilots or ground vehicle operators may not be alerted when traffic does not pose a risk to their aircraft.
[0048] In some examples, at **626**, determining that the target traffic meets the one or more runway occupancy criteria comprises determining that the target traffic is located on a runway. In this manner, the runway occupancy alert is not output if the runway is not occupied.
[0049] The method **600** further comprises, at **628**, based upon determining that the aircraft and the target traffic meet the one or more runway occupancy criteria, outputting the runway occupied alert. In some examples, at **630**, outputting the runway occupied alert comprises providing one or more of visual, auditory, or haptic feedback to an operator of the aircraft. FIG. **6** shows several examples of a runway occupied alert, including a visual notification **318**, an audible notification **320**, and haptic feedback. In this manner, the tablet computing device can alert pilot(s) and/or other vehicle operators of potential traffic conflicts.
[0050] Providing an automated runway occupied alert can allow pilots to respond to surrounding traffic. The alerting system provides an additional measure of situational awareness in low-

visibility conditions (e.g., adverse weather), and can continuously or periodically scan the aircraft's surroundings for traffic, even at airports without tower control or radar coverage. As described above, the location data is processed with one or more ownship alert criteria and one or more target traffic alert criteria. This enables an accurate alert to be output sufficiently early for the pilots to communicate with the target traffic and/or air traffic control, or to hold short of or exit a runway. This supplements human judgment and communication, reducing reliance on human factors and ensuring situational awareness.

[0051] In some embodiments, the methods and processes described herein may be tied to a computing system of one or more computing devices. In particular, such methods and processes may be implemented as a computer-application program or service, an application-programming interface (API), a library, and/or other computer-program product.

[0052] FIG. **7** schematically shows a non-limiting embodiment of a computing system **700** that can enact one or more of the methods and processes described above. Computing system **700** is shown in simplified form. Computing system **700** may embody the computing system **102** described above and illustrated in FIG. **1**. Components of computing system **700** may be included in one or more personal computers, server computers, tablet computers, home-entertainment computers, network computing devices, video game devices, mobile computing devices, mobile communication devices (e.g., smartphone), a flight control computer, a flight management computer, and/or other computing devices, and wearable computing devices such as smart wristwatches and head mounted augmented reality devices.

[0053] Computing system **700** includes processing circuitry **702**, volatile memory **704**, and a non-volatile storage device **706**. Computing system **700** may optionally include a display subsystem **708**, input subsystem **710**, communication subsystem **712**, and/or other components not shown in FIG. **7**.

[0054] The processing circuitry **702** typically includes one or more logic processors, which are physical devices configured to execute instructions. For example, the logic processors may be configured to execute instructions that are part of one or more applications, programs, routines, libraries, objects, components, data structures, or other logical constructs. Such instructions may be implemented to perform a task, implement a data type, transform the state of one or more components, achieve a technical effect, or otherwise arrive at a desired result.

[0055] The logic processor may include one or more physical processors configured to execute software instructions. Additionally or alternatively, the logic processor may include one or more hardware logic circuits or firmware devices configured to execute hardware-implemented logic or firmware instructions. Processors of the processing circuitry **702** may be single-core or multi-core, and the instructions executed thereon may be configured for sequential, parallel, and/or distributed processing. Individual components of the processing circuitry optionally may be distributed among two or more separate devices, which may be remotely located and/or configured for coordinated processing. For example, aspects of the computing system disclosed herein may be virtualized and executed by remotely accessible, networked computing devices configured in a cloud-computing configuration. In such a case, these virtualized aspects are run on different physical logic processors of various different machines, it will be understood. These different physical logic processors of the different machines will be understood to be collectively encompassed by processing circuitry **702**.

[0056] Non-volatile storage device **706** includes one or more physical devices configured to hold instructions executable by the processing circuitry to implement the methods and processes described herein. When such methods and processes are implemented, the state of non-volatile storage device **706** may be transformed—e.g., to hold different data.

[0057] Non-volatile storage device **706** may include physical devices that are removable and/or built in. Non-volatile storage device **706** may include optical memory, semiconductor memory, and/or magnetic memory, or other mass storage device technology. Non-volatile storage device **706** may include nonvolatile, dynamic, static, read/write, read-only, sequential-access, location-addressable, file-addressable, and/or content-addressable devices. It will be appreciated that non-volatile storage device **706** is configured to hold instructions even when power is cut to the non-volatile storage device **706**.

[0058] Volatile memory **704** may include physical devices that include random access memory. Volatile memory **704** is typically utilized by processing circuitry **702** to temporarily store information during processing of software instructions. It will be appreciated that volatile memory **704** typically does not continue to store instructions when power is cut to the volatile memory **704**.

[0059] Aspects of processing circuitry **702**, volatile memory **704**, and non-volatile storage device **706** may be integrated together into one or more hardware-logic components. Such hardware-logic components may include field-programmable gate arrays (FPGAs), program- and application-specific integrated circuits (PASIC/ASICs), program- and application-specific standard products (PSSP/ASSPs), system-on-a-chip (SOC), and complex programmable logic devices (CPLDs), for example.

[0060] The term “program” may be used to describe an aspect of computing system **700** typically implemented in software by a processor to perform a particular function using portions of volatile memory, which function involves transformative processing that specially configures the processor to perform the function. Thus, a program may be instantiated via processing circuitry **702** executing instructions held by non-volatile storage device **706**, using portions of volatile memory **704**. It will be understood that different programs may be instantiated from the same application, service, code block, object, library, routine, API, function, etc. Likewise, the same program may be instantiated by different applications, services, code blocks, objects, routines, APIs, functions, etc. The term “program” may encompass individual or groups of executable files, data files, libraries, drivers, scripts, database records, etc.

[0061] When included, display subsystem **708** may be used to present a visual representation of data held by non-volatile storage device **706**. The visual representation may take the form of a GUI. As the herein described methods and processes change the data held by the non-volatile storage device, and thus transform the state of the non-volatile storage device, the state of display subsystem **708** may likewise be transformed to visually represent changes in the underlying data. Display subsystem **708** may include one or more display devices utilizing virtually any type of technology. Such display devices may be combined with processing circuitry **702**, volatile memory **704**, and/or non-volatile storage device **706** in a shared enclosure, or such display devices may be peripheral display devices.

[0062] When included, input subsystem **710** may comprise or interface with one or more user-input devices such as a keyboard, mouse, touch screen, camera, or microphone.

[0063] When included, communication subsystem **712** may be configured to communicatively couple various computing devices described herein with each other, and with other devices. Communication subsystem **712** may include wired and/or wireless communication devices compatible with one or more different communication protocols. As non-limiting examples, the communication subsystem may be configured for communication via a wired or wireless local- or wide-area network, broadband cellular network, etc. In some embodiments, the communication subsystem may allow computing system **700** to send and/or receive messages to and/or from other devices via a network such as the Internet.

[0064] Further, the disclosure comprises configurations according to the following clauses.

[0065] Clause 1. At a computing device, a method for providing an automated runway occupied alert, the method comprising: receiving, from a location sensor on board an aircraft, location sensor data for the aircraft; receiving location data for target traffic; based on the location sensor data for the aircraft, determining a location, a speed, and a direction of travel for the aircraft; based on the location data for the target traffic, determining a location, a speed, and a direction of travel for the target traffic; determining, based at least on the location sensor data for the aircraft, that the aircraft meets one or more runway occupancy criteria; determining, based on the location data for the target traffic, that the target traffic meets the one or more runway occupancy criteria; and based upon determining that the aircraft and the target traffic meet the one or more runway occupancy criteria, outputting the runway occupied alert.

[0066] Clause 2. The method of clause 1, wherein receiving the location sensor data for the aircraft comprises receiving one or more of GPS data from a GPS sensor or accelerometer data from an accelerometer on board the aircraft.

[0067] Clause 3. The method of clause 1, wherein receiving the location data for the target traffic comprises receiving ADS-B data from an ADS-B receiver communicatively coupled with the computing device, and using the ADS-B data to determine a location of the target traffic.

[0068] Clause 4. The method of clause 1, wherein the target traffic comprises one or more of another aircraft or a ground vehicle.

[0069] Clause 5. The method of clause 1, wherein outputting the runway occupied alert comprises providing one or more of visual, auditory, or haptic feedback to an operator of the aircraft.

[0070] Clause 6. The method of clause 1, wherein one or more of determining that the aircraft meets the one or more runway occupancy criteria or determining that the target traffic meets the one or more runway occupancy criteria comprises determining that the aircraft or the target traffic, respectively, is at or within a threshold distance to a runway threshold.

[0071] Clause 7. The method of clause 1, wherein one or more of determining that the aircraft meets the one or more runway occupancy criteria or determining that the target traffic meets the one or more runway occupancy criteria comprises determining that the aircraft or the target traffic, respectively, does not qualify for more than one runway.

[0072] Clause 8. The method of clause 1, wherein determining that the target traffic meets the one or more runway occupancy criteria comprises determining that the target traffic is grounded.

[0073] Clause 9. The method of clause 1, wherein determining that the target traffic meets the one or more runway occupancy criteria comprises determining that the target traffic is not diverging from the aircraft.

[0074] Clause 10. The method of clause 1, wherein determining that the target traffic meets the one or more runway occupancy criteria comprises determining that the target traffic is located on a runway.

[0075] Clause 11. A computing system, comprising: one or more processors configured to, receive, from a location sensor on board an aircraft, location sensor data for the aircraft; receive location data for target traffic; based on the location sensor data for the aircraft, determine a location, a speed, and a direction of travel for the aircraft; based on the location data for the target traffic, determine a location, a speed, and a direction of travel for the target traffic; determine, based at least on the location sensor data for the aircraft, that the aircraft meets one or more runway occupancy criteria; determine, based on the location data for the target traffic, that the target traffic meets the one or more runway occupancy criteria; and based upon determining that the aircraft and the target traffic meet the one or more runway occupancy criteria, output a runway occupied alert.

[0076] Clause 12. The computing system of clause 11, wherein the location sensor data comprises one or more of GPS data from a GPS sensor or accelerometer data from an accelerometer on board the aircraft.

[0077] Clause 13. The computing system of clause 11, wherein the location data for the target traffic comprises ADS-B data from an ADS-B receiver communicatively coupled with the computing system, and wherein the one or more processors are further configured to use the ADS-B data to determine the location of the target traffic.

[0078] Clause 14. The computing system of clause 11, wherein the one or more runway occupancy criteria include a threshold distance to a runway threshold.

[0079] Clause 15. The computing system of clause 11, wherein the one or more processors are further configured to determine that the aircraft and/or the target traffic does not qualify for more

than one runway.
[0080] Clause 16. The computing system of clause 11, wherein the one or more processors are further configured to determine that the aircraft and/or the target traffic is grounded.
[0081] Clause 17. The computing system of clause 11, wherein the one or more processors are further configured to determine that the target traffic is not diverging from the aircraft.
[0082] Clause 18. The computing system of clause 11, wherein the one or more processors are further configured to determine that the target traffic is located on a runway.
[0083] Clause 19. The computing system of clause 11, wherein the runway occupied alert comprises one or more of visual, auditory, or haptic feedback.
[0084] Clause 20. A computing system, comprising: a GPS sensor on board an aircraft, the GPS sensor configured to output GPS sensor data; a location data receiver configured to receive location data for target traffic; and one or more processors configured to, receive the GPS sensor data from the GPS sensor; based on the GPS sensor data for the aircraft, determine a position, a speed, and a direction of travel for the aircraft; use the location data for the target traffic to determine a location, a speed, and a direction of travel for the target traffic; determine, based at least on the location sensor data for the aircraft, that the aircraft meets one or more runway occupancy criteria; determine, based on the location data for the target traffic, that the target traffic meets the one or more runway occupancy criteria; and based upon determining that the aircraft and the target traffic meet the one or more runway occupancy criteria, output a runway occupied alert.
[0085] “And/or” as used herein is defined as the inclusive or V, as specified by the following truth table:
TABLE-US-00001 A B A ∨ B True True True True False True False True True False False False
[0086] The terminology “one or more of A or B” as used herein comprises A, B, or a combination of A and B. The terminology “one or more of A, B, or C” is equivalent to A, B, and/or C. As such, “one or more of A, B, or C” as used herein comprises A individually, B individually, C individually, a combination of A and B, a combination of A and C, a combination of B and C, or a combination of A, B and C.
[0087] It will be understood that the configurations and/or approaches described herein are exemplary in nature, and that these specific embodiments or examples are not to be considered in a limiting sense, because numerous variations are possible. The specific routines or methods described herein may represent one or more of any number of processing strategies. As such, various acts illustrated and/or described may be performed in the sequence illustrated and/or described, in other sequences, in parallel, or omitted. Likewise, the order of the above-described processes may be changed.
[0088] The subject matter of the present disclosure includes all novel and non-obvious combinations and sub-combinations of the various processes, systems and configurations, and other features, functions, acts, and/or properties disclosed herein, as well as any and all equivalents thereof.

Claims

1. At a computing device, a method for providing an automated runway occupied alert, the method comprising: receiving, from a location sensor on board an aircraft, location sensor data for the aircraft; receiving location data for target traffic; based on the location sensor data for the aircraft, determining a location, a speed, and a direction of travel for the aircraft; based on the location data for the target traffic, determining a location, a speed, and a direction of travel for the target traffic; determining, based at least on the location sensor data for the aircraft, that the aircraft meets one or more runway occupancy criteria; determining, based on the location data for the target traffic, that the target traffic meets the one or more runway occupancy criteria; and based upon determining that the aircraft and the target traffic meet the one or more runway occupancy criteria, outputting the runway occupied alert.

2. The method of claim 1, wherein receiving the location sensor data for the aircraft comprises receiving one or more of GPS data from a GPS sensor or accelerometer data from an accelerometer on board the aircraft.

3. The method of claim 1, wherein receiving the location data for the target traffic comprises receiving ADS-B data from an ADS-B receiver communicatively coupled with the computing device, and using the ADS-B data to determine a location of the target traffic.

4. The method of claim 1, wherein the target traffic comprises one or more of another aircraft or a ground vehicle.

5. The method of claim 1, wherein outputting the runway occupied alert comprises providing one or more of visual, auditory, or haptic feedback to an operator of the aircraft.

6. The method of claim 1, wherein one or more of determining that the aircraft meets the one or more runway occupancy criteria or determining that the target traffic meets the one or more runway occupancy criteria comprises determining that the aircraft or the target traffic, respectively, is at or within a threshold distance to a runway threshold.

7. The method of claim 1, wherein one or more of determining that the aircraft meets the one or more runway occupancy criteria or determining that the target traffic meets the one or more runway occupancy criteria comprises determining that the aircraft or the target traffic, respectively, does not qualify for more than one runway.

8. The method of claim 1, wherein determining that the target traffic meets the one or more runway occupancy criteria comprises determining that the target traffic is grounded.

9. The method of claim 1, wherein determining that the target traffic meets the one or more runway occupancy criteria comprises determining that the target traffic is not diverging from the aircraft.

10. The method of claim 1, wherein determining that the target traffic meets the one or more runway occupancy criteria comprises determining that the target traffic is located on a runway.

11. A computing system, comprising: one or more processors configured to, receive, from a location sensor on board an aircraft, location sensor data for the aircraft; receive location data for target traffic; based on the location sensor data for the aircraft, determine a location, a speed, and a direction of travel for the aircraft; based on the location data for the target traffic, determine a location, a speed, and a direction of travel for the target traffic; determine, based at least on the location sensor data for the aircraft, that the aircraft meets one or more runway occupancy criteria; determine, based on the location data for the target traffic, that the target traffic meets the one or more runway occupancy criteria; and based upon determining that the aircraft and the target traffic meet the one or more runway occupancy criteria, output a runway occupied alert.

12. The computing system of claim 11, wherein the location sensor data comprises one or more of GPS data from a GPS sensor or accelerometer data from an accelerometer on board the aircraft.

13. The computing system of claim 11, wherein the location data for the target traffic comprises ADS-B data from an ADS-B receiver communicatively coupled with the computing system, and wherein the one or more processors are further configured to use the ADS-B data to determine the location of the target traffic.

14. The computing system of claim 11, wherein the one or more runway occupancy criteria include a threshold distance to a runway threshold.

15. The computing system of claim 11, wherein the one or more processors are further configured to determine that the aircraft and/or the target traffic does not qualify for more than one runway.

16. The computing system of claim 11, wherein the one or more processors are further configured to determine that the aircraft and/or the target traffic is grounded.

17. The computing system of claim 11, wherein the one or more processors are further configured to determine that the target traffic is not diverging from the aircraft.

18. The computing system of claim 11, wherein the one or more processors are further configured to determine that the target traffic is located on a runway.

19. The computing system of claim 11, wherein the runway occupied alert comprises one or more of visual, auditory, or haptic feedback.

20. A computing system, comprising: a GPS sensor on board an aircraft, the GPS sensor configured to output GPS sensor data; a location data receiver configured to receive location data for target traffic; and one or more processors configured to, receive the GPS sensor data from the GPS sensor; based on the GPS sensor data for the aircraft, determine a position, a speed, and a direction of travel for the aircraft; use the location data for the target traffic to determine a location, a speed, and a direction of travel for the target traffic; determine, based at least on the location sensor data for the aircraft, that the aircraft meets one or more runway occupancy criteria; determine, based on the location data for the target traffic, that the target traffic meets the one or more runway occupancy criteria; and based upon determining that the aircraft and the target traffic meet the one or more runway occupancy criteria, output a runway occupied alert.