MOBILE WIRING HARNESS ANOMALY DETECTION SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Patent Application Serial No. 63/516,215, filed July 28, 2023, and entitled "Mobile Wiring Harness Anomaly Detection System," which is incorporated herein by reference in its entirety.

BACKGROUND INFORMATION

1. Field:

[0002] The present disclosure relates generally to inspecting and in particular, to inspecting wiring systems for vehicles during manufacturing and maintenance.

2. Background:

[0003] Wiring harnesses are installed in different vehicles such as aircraft, ground vehicles, marine vessels, spacecraft, and other types of vehicles. A wiring harness is an assembly of electrical cables or wires that transmit electrical signals or electrical power. These cables are secured or bound together by components such as straps, ties, sleeves, tape, conduits, or other types of components.

[0004] Wiring harnesses are used in vehicles to help simplify the installation of different electrical components. The use of wiring harnesses can also reduce time and installation costs while improving system rubber viability. For example, aircraft wiring harnesses can be used to connect different electrical components such as avionics equipment, navigation systems, computers,

lighting systems, entertainment systems, and other systems and components in aircraft.

[0005] The use of wiring harnesses and aircraft enables bundling many wires into a single unit. The wires in a wiring harness can have a specific and known path reducing complexity in time for installation and inspection. Further, wiring harnesses are designed to withstand various environmental conditions and can increase the safety and reliability of electronic systems in aircraft.

SUMMARY

[0006] An embodiment of the present disclosure provides an aerospace wiring harness inspection system comprising a mobile personal computing device; a camera system connected to the mobile personal computing device, a machine learning model running in the mobile personal computing device; and a controller. The machine learning model is trained to detect anomalies in a set of images of a wiring harness in an aerospace vehicle. The controller configured to control the camera system to generate a set of images of the wiring harness; send the set of images of the wiring harness to the machine learning model; and receive a result from the machine learning model indicating whether an anomaly is present in the wiring harness.

[0007] Another embodiment of the present disclosure provides a platform wiring inspection system comprising a mobile personal computing device; a camera system connected to the mobile personal computing device; a machine learning model running in the mobile personal computing device; and a controller. The machine learning model is trained to detect anomalies in images of wiring harnesses for a platform. The controller configured to control the camera system to generate a set of images of a wiring harness; send the set of images of the wiring harness to the machine learning model; and receive a result from the machine learning model indicating whether an anomaly is present in the wiring harness.

[0008] Still another embodiment of the present disclosure provides a method for inspecting a wiring harness in an aerospace vehicle. A computer system controls a camera system to generate a set of images of the wiring harness in the vehicle, wherein the camera

system is connected to the mobile personal computing device. The computer system sends the set of images of the wiring harness to a machine learning model, wherein the machine learning model is trained to detect anomalies in a set of images of a wiring harness in an aerospace vehicle. The computer system receives a result from the machine learning model indicating whether an anomaly is present in the wiring harness in the aerospace vehicle.

[0009] The features and functions can be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments in which further details can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The novel features believed characteristic of the illustrative embodiments are set forth in the appended claims. The illustrative embodiments, however, as well as a preferred mode of use, further objectives and features thereof, will best be understood by reference to the following detailed description of an illustrative embodiment of the present disclosure when read in conjunction with the accompanying drawings, wherein:

[0011] **Figure 1** is a pictorial representation of a network of data processing systems in which illustrative embodiments may be implemented;

[0012] **Figure 2** is an illustration of a block diagram of an inspection environment in accordance with an illustrative embodiment;

[0013] **Figure 3** is an illustration of object recognition using a compilation on neural network-based computer vision out in accordance with an illustrative embodiment;

[0014] **Figure 4** is an illustration of anomaly detection using a machine learning model in accordance with an illustrative embodiment;

[0015] **Figure 5** is an illustration of machine learning model training in accordance with an illustrative embodiment;

[0016] **Figure 6** is an illustration of wires and cables with anomalies in accordance with an illustrative embodiment;

[0017] **Figure 7** is an illustration of a table wiring components and anomalies for wiring components are with recommended dispositions in accordance with an illustrative embodiment;

[0018] **Figure 8** is an illustration of a dataflow diagram for training machine learning model using a synthetic dataset in accordance with an illustrative embodiment;

[0019] **Figure 9** is an illustration of a dataflow diagram using information from engineering standard handbooks to create computer-aided design models and actions for different anomalies in accordance with an illustrative embodiment;

[0020] **Figure 10** is an illustration of a dataflow diagram for performing actions to rework wiring harnesses in accordance with an illustrative embodiment;

[0021] **Figure 11** is an illustration of a dataflow diagram for transfer learning of machine learning models for use in a handheld scanner in accordance with an illustrative embodiment;

[0022] **Figure 12** is an illustration of teacher-student transfer learning in accordance with an illustrative embodiment;

[0023] **Figure 13** is an illustration of a feedback loop for machine learning model performance enhancement in accordance with an illustrative embodiment;

[0024] **Figure 14** is an illustration of a data flow diagram for image augmentation in accordance with an illustrative embodiment;

[0025] **Figure 15** is an illustration of a data flow diagram for labeling and parameter extraction in accordance with an illustrative embodiment;

[0026] **Figure 16** is an illustration of a data flow diagram for synthetic image generation in accordance with an illustrative embodiment;

[0027] **Figure 17** is an illustration of a flowchart of a process for inspecting a wiring harness in an aerospace vehicle in accordance with an illustrative embodiment;

[0028] **Figure 18** is an illustration of a flowchart of a process for creating training data in accordance with an illustrative embodiment;

[0029] **Figure 19** is an illustration of a flowchart of process for selecting images in accordance with an illustrative embodiment;

[0030] **Figure 20** is an illustration of a flowchart of a process for generating training data in accordance with an illustrative embodiment;

[0031] **Figure 21** is an illustration of a flowchart of a process for generating training data in accordance with an illustrative embodiment;

[0032] **Figure 22** is an illustration of a flowchart of a process for training a machine learning model for use in a mobile personal computing device in accordance with an illustrative embodiment;

[0033] **Figure 23** is an illustration of a flowchart of a process for performing a remedial action in accordance with an illustrative embodiment;

[0034] **Figure 24** is an illustration of a block diagram of a data processing system in accordance with an illustrative embodiment;

[0035] **Figure 25** is an illustration of an aircraft manufacturing and service method in accordance with an illustrative embodiment; and

[0036] **Figure 26** is an illustration of a block diagram of an aircraft in which an illustrative embodiment may be implemented.

DETAILED DESCRIPTION

[0037] The illustrative embodiments recognize and take into account one or more different considerations. For example, monitoring the health of wiring party systems is important in determining proper maintenance and rework as needed. With large commercial aircraft, the amount of wiring can exceed a hundred miles. For example, a commercial aircraft may have 330 or more miles of wiring. Further with the use of wiring harnesses, a complex network of interconnected cables extends through the aircraft connecting various systems components.

[0038] As result, inspecting the different wiring harnesses in an aircraft can be more difficult than desired.

[0039] Thus, the illustrative examples provide a system, apparatus, method, and computer program product for inspecting wiring harnesses for platforms such as aerospace vehicles. An aerospace wiring harness inspection system comprises a mobile personal computing device; a camera system connected to the mobile personal computing device, a machine learning model running in the mobile personal computing device; and a controller. The machine learning model is trained to detect anomalies in a set of images of a wiring harness in an aerospace vehicle. The controller configured to control the camera system to generate a set of images of the wiring harness; send the set of images of the wiring harness to the machine learning model; and receive a result from the machine learning model indicating whether an anomaly is present in the wiring harness.

[0040] Further, the illustrative examples provide an ability to generate sufficient amounts of training data to train machine learning models in detecting anomalies

in wiring harnesses with a desired level of accuracy. Additional training data can be added to the training datasets the different examples through the use of image augmentation, image creation using models and anomaly definitions from engineering standard handbooks that define and illustrate anomalies for wire and cable systems. Further, the illustrative examples provide an ability to increase accuracy in detecting anomalies for particular fleets over time through feedback loops. These and other illustrative features are described herein.

[0041] With reference now to the figures and, in particular, with reference to **Figure 1**, a pictorial representation of a network of data processing systems is depicted in which illustrative embodiments may be implemented. Network data processing system **100** is a network of computers in which the illustrative embodiments may be implemented. Network data processing system **100** contains network **102**, which is the medium used to provide communications links between various devices and computers connected together within network data processing system **100**. Network **102** may include connections, such as wire, wireless communication links, or fiber optic cables.

[0042] In the depicted example, server computer **104** and server computer **106** connect to network **102** along with storage unit **108**. In addition, client devices **110** connect to network **102**. Client devices **110** can be, for example, computers, workstations, network computers, vehicles, machinery, appliances, or other devices that can process data. As depicted in this example, client devices **110** include client computer **112**, extension rod **114**, handheld scanner **116 116**, mobile phone **118**, tablet computer **120**, and smart glasses **122**. Client devices **110**

can also include, for example, computers, workstations, or network computers. In the depicted example, server computer **104** provides information, such as boot files, operating system images, and applications to client devices **110.**

[0043] In the depicted example, server computer **104** provides information, such as boot files, operating system images, and applications to client devices **110.** Further, in this illustrative example, server computer **104**, server computer **106**, storage unit **108**, and client devices **110** are network devices that connect to network **102** in which network **102** is the communications media for these network devices. Some or all of client devices **110** may form an Internet of Things (IoT) in which these physical devices can connect to network **102** and exchange information with each other over network **102.**

[0044] Client devices **110** are clients to server computer **104** in this example. Network data processing system **100** may include additional server computers, client computers, and other devices not shown. Client devices **110** connect to network **102** utilizing at least one of wired, optical fiber, or wireless connections.

[0045] Program instructions located in network data processing system **100** can be stored on a computer-recordable storage medium and downloaded to a data processing system or other device for use. For example, program instructions can be stored on a computer-recordable storage medium on server computer **104** and downloaded to client devices **110** over network **102** for use on client devices **110.**

[0046] In the depicted example, network data processing system **100** is the Internet with network **102** representing a worldwide collection of networks and gateways that use the Transmission Control

Protocol/Internet Protocol (TCP/IP) suite of protocols or other networking protocols to communicate with one another. At the heart of the Internet is a backbone of high-speed data communication lines between major nodes or host computers consisting of thousands of commercial, governmental, educational, and other computer systems that route data and messages. Of course, network data processing system **100** also may be implemented using a number of different types of networks. For example, network **102** can be comprised of at least one of the Internet, an intranet, a local area network (LAN), a metropolitan area network (MAN), or a wide area network (WAN). **Figure 1** is intended as an example, and not as an architectural limitation for the different illustrative embodiments.

[0047] In this illustrative example, client devices **110** include personal mobile inspection devices **111**. Personal mobile inspection devices **111** are any computing devices that can be held or worn by a person. Further, personal mobile inspection devices **111** also include camera systems that can generate images **129**. In this example, personal mobile inspection devices **111** comprise extension rod **114**, handheld scanner **116**, mobile phone **118**, tablet computer **120**, and smart glasses **122** can be used to inspect wiring harnesses in platform such as commercial aircraft **130**.

[0048] In one illustrative example, one or more of personal mobile inspection devices **111** can be operated by a human operator to generate images **129** of wiring harnesses in commercial aircraft **130**.

[0049] In one illustrative example, images **129** from these personal mobile inspection devices can be sent to inspection manager **131** over network **102**. In this example, inspection manager **131** is located on server

computer **104**. As depicted, inspection manager **131** uses machine learning model **132** to determine whether anomalies are present in one or more of the wiring harnesses in commercial aircraft **130**.

[0050] In another illustrative example, a personal mobile inspection device can operate in a standalone fashion. For example, handheld scanner **116** can generate and analyze images without sending images to inspection manager **131** for analysis. With this example, inspection manager **133** and machine learning model **134** are located in handheld scanner **116**. With this implementation, machine learning model **134** has a smaller size as compared to machine learning model **132**. The size of machine learning model **134** is selected to enable machine learning model **134** to be located on and run on handheld scanner **116**. In this example, machine learning model **134** can be created using knowledge distillation in which a teacher machine learning model trains a student machine learning model. In this example, machine learning model **134** is the resulting student model.

[0051] As used herein, "a number of" when used with reference to items, means one or more items. For example, "a number of different types of networks" is one or more different types of networks.

[0052] Further, the phrase "at least one of," when used with a list of items, means different combinations of one or more of the listed items can be used, and only one of each item in the list may be needed. In other words, "at least one of" means any combination of items and number of items may be used from the list, but not all of the items in the list are required. The item can be a particular object, a thing, or a category.

[0053] For example, without limitation, "at least one of item A, item B, or item C" may include item A, item A

and item B, or item B. This example also may include item A, item B, and item C or item B and item C. Of course, any combination of these items can be present. In some illustrative examples, "at least one of" can be, for example, without limitation, two of item A; one of item B; and ten of item C; four of item B and seven of item C; or other suitable combinations.

[0054] With reference now to **Figure 2**, an illustration of a block diagram of an inspection environment is depicted in accordance with an illustrative embodiment. In this illustrative example, inspection environment **200** includes components that can be implemented in hardware such as the hardware shown in network data processing system **100** in **Figure 1**. In this example, wiring harness inspection system **202** can operate to inspect wiring harnesses **203** in platform **204**. This inspection is performed to determine whether anomalies **205** is present in wiring harnesses **203** in platform **204**.

[0055] In this depicted example, platform **204** takes the form of aerospace vehicle **206**. Aerospace vehicle **206** can include both atmospheric vehicles and space vehicles. For example, aerospace vehicle **206** can be an a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a spacecraft, a jet aircraft, and a space shuttle, or other type of aerospace vehicle. When used to inspect aerospace vehicle **206**, wiring harness inspection system **202** is aerospace wiring harness inspection system **211**.

[0056] In this illustrative example, wiring harness inspection system **202** comprises computer system **212**, camera system **213**, inspection manager **214**. Camera system

213 comprises one or more cameras. Camera system **213** is connected to computer system **212**.

[0057] In this example, inspection manager **214** is located in computer system **212**. Inspection manager **214** can be implemented in software, hardware, firmware or of other commitments to a combination thereof. When software is used, the operations performed by inspection manager **214** can be implemented in program instructions configured to run on hardware, such as a processor unit. When firmware is used, the operations performed by inspection manager **214** can be implemented in program instructions and data and stored in persistent memory to run on a processor unit. When hardware is employed, the hardware can include circuits that operate to perform the operations in inspection manager **214**.

[0058] In the illustrative examples, the hardware can take a form selected from at least one of a circuit system, an integrated circuit, an application specific integrated circuit (ASIC), a programmable logic device, or some other suitable type of hardware configured to perform a number of operations. With a programmable logic device, the device can be configured to perform the number of operations. The device can be reconfigured at a later time or can be permanently configured to perform the number of operations. Programmable logic devices include, for example, a programmable logic array, a programmable array logic, a field-programmable logic array, a field-programmable gate array, and other suitable hardware devices. Additionally, the processes can be implemented in organic components integrated with inorganic components and can be comprised entirely of organic components excluding a human being. For example, the processes can be implemented as circuits in organic semiconductors.

[0059] As used herein, "a number of" when used with reference to items, means one or more items. For example, "a number of operations" is one or more operations.

[0060] Further, the phrase "at least one of," when used with a list of items, means different combinations of one or more of the listed items can be used, and only one of each item in the list may be needed. In other words, "at least one of" means any combination of items and number of items may be used from the list, but not all of the items in the list are required. The item can be a particular object, a thing, or a category.

[0061] For example, without limitation, "at least one of item A, item B, or item C" may include item A, item A and item B, or item B. This example also may include item A, item B, and item C or item B and item C. Of course, any combination of these items can be present. In some illustrative examples, "at least one of" can be, for example, without limitation, two of item A; one of item B; and ten of item C; four of item B and seven of item C; or other suitable combinations.

[0062] Computer system **212** is a physical hardware system and includes one or more data processing systems. When more than one data processing system is present in computer system **212**, those data processing systems are in communication with each other using a communications medium. The communications medium can be a network. The data processing systems can be selected from at least one of a computer, a server computer, a tablet computer, or some other suitable data processing system.

[0063] As depicted, computer system **212** includes a number of processor units **216** that are capable of executing program instructions **218** implementing processes

in the illustrative examples. In other words, program instructions **218** are computer-readable program instructions.

[0064] As used herein, a processor unit in the number of processor units **216** is a hardware device and is comprised of hardware circuits such as those on an integrated circuit that respond to and process instructions and program code that operate a computer. When the number of processor units **216** executes program instructions **218** for a process, the number of processor units **216** can be one or more processor units that are in the same computer or in different computers. In other words, the process can be distributed between processor units **216** on the same or different computers in computer system **212**.

[0065] Further, the number of processor units **216** can be of the same type or different types of processor units. For example, the number of processor units **216** can be selected from at least one of a single core processor, a dual-core processor, a multi-processor core, a general-purpose central processing unit (CPU), a graphics processing unit (GPU), a digital signal processor (DSP), or some other type of processor unit.

[0066] In this illustrative example, inspection manager **214** controls camera system **213** to generate a set of images **220** of wiring harness **222** in wiring harnesses **203**. In this example, camera system **213** sends images **220** to inspection manager **214** for analysis. Inspection manager **214** sends the set of images **220** to machine learning model **224**. Machine learning model **224** can be implemented using a neural network, a random forest model, a decision tree, a convolutional neural network (CNN), a recurrent neural network (RNN), a generative machine learning model trained using a generative

adversarial network (GAN), a transfer learning model, and other suitable types of machine learning models.

[0067] In this example, machine learning model **224** is trained to detect anomaly **228** in a set of images **220** of wiring harness **222** in platform **204**, such as aerospace vehicle **206**. In response, inspection manager **214** receives result **226** from the machine learning model indicating whether anomaly **228** is present in wiring harness **222**.

[0068] In one illustrative example, computer system **212** includes mobile personal inspection device **240**. With this example, mobile personal inspection device **240** can be a computing device that can be held or worn by human operator **241**. Mobile personal inspection device **240** can be selected from a group comprising an extension rod, a handheld scanner, a smart phone, a mobile phone, a tablet, smart glasses, augmented reality goggles, a laptop computer, a smart watch, or other device.

[0069] In this example, camera system **213** is connected to mobile personal inspection device **240**. When one component is "connected" to another component, the connection is a physical connection. For example, a first component, camera system **213**, can be considered to be physically connected to a second component, mobile personal inspection device **240**, by at least one of being secured to the second component, bonded to the second component, mounted to the second component, welded to the second component, fastened to the second component, or connected to the second component in some other suitable manner. The first component also can be connected to the second component using a third component. The first component can also be considered to be physically connected to the second component by being formed as part

of the second component, an extension of the second component, or both.

[0070] With this example, mobile personal inspection device **240** generates images **220** using camera system **213** and sends images **220** to inspection manager **214** for analysis.

[0071] In another illustrative example, mobile personal inspection device **240** can operate as a stand-alone device without needing to send images over a network or wireless connection for analysis. With this example, inspection manager **214** and machine learning model **224** can be located and mobile personal inspection device **240**.

[0072] In one illustrative example, one or more technical solutions are present that overcome a technical problem with identifying anomalies in long lengths of wiring harnesses in aerospace vehicles. As a result, one or more solutions may provide a technical effect enabling the creation of machine learning models that provide a desired level accuracy in identifying anomalies in wiring harnesses located in platforms such as aerospace vehicles.

[0073] The use of the wiring harness inspection system in the different illustrative examples can result in identifying anomalies in wiring harnesses more efficiently as compared to current techniques. The use of machine learning models with specialized training datasets and training operations for training machine learning models that focus on wiring harnesses for aerospace vehicles can result in increased efficiency in identifying anomalies. In the different illustrative examples, the training datasets can be generated in a manner that provides increased amounts of training data

for training machine learning models to identify wiring harness anomalies.

[0074] Further, with the use of feedback loops and continued training machine learning models, the aerospace wiring harness inspection system can have increasing accuracy in identifying anomalies. This increase in accuracy can be focused on specific aircraft fleets through the use of the wiring harness inspection system on those specific aircraft leads. Further, by continuing to train machine learning models based on images from those aircraft fleets, the machine learning models can more efficiently and accurately identify anomalies that occur over time that are specific to those aircraft fleets.

[0075] Additionally, the aerospace wiring harness inspection system can be implemented in mobile personal computing devices such as handheld scanners, mobile phones, smart glasses, and other devices. In these illustrative examples, the machine learning models can be created for use in these mobile personal computing devices such that the mobile computing devices can function as standalone devices without needing to send images to another location for analysis.

[0076] Computer system **212** can be configured to perform at least one of the steps, operations, or actions described in the different illustrative examples using software, hardware, firmware or a combination thereof. As a result, computer system **212** operates as a special purpose computer system in which inspection manager **214** in computer system **212** enables at least one of more efficient or more accurate inspections to identify anomalies **205** and wiring harnesses **203**. In particular, inspection manager **214** transforms computer system **212** into a special purpose computer system as compared to

currently available general computer systems that do not have inspection manager **214**.

[0077] The illustration of inspection environment **200** in **Figure 2** is not meant to imply physical or architectural limitations to the manner in which an illustrative embodiment may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be unnecessary. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in an illustrative embodiment.

[0078] For example, wiring harness inspection system **202** can be used to inspect wiring harnesses in other platforms in addition to or in place of the aerospace vehicle **206**. For example, platform **204** can be selected from a group comprising a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, an aircraft, a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle a personal air vehicle, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, and a building. Wiring harness inspection system **202** can also be referred to as an aerospace wiring harness inspection system.

[0079] With reference next to **Figure 3**, an illustration of object recognition using a compilation on neural network-based computer vision out is depicted in accordance with an illustrative embodiment. In this

example, convolutional neural network (CNN) **300** is an example of an implementation of machine learning model **224** in **Figure 2.**

[0080] In this illustrative example, convolutional neural network **300** can receive camera image **302** containing wiring harness **303** and generate a bill of materials (BOM) **304** for anomalies identified for the wiring harness in camera image **302.** Further, bill of materials **304** can also include a history of anomalies, rework, maintenance, or other actions taken with respect to wiring harness **303.**

[0081] In this illustrative example, convolutional neural network **300** performs object recognition **310** using computer vision algorithms. In this example, the computer vision algorithms for object recognition **310** can include a number of different components such as image segmentation **312,** object detection **314,** image classification **316,** object localization **318.**

[0082] In this example, image segmentation **312** can include separating pixels in camera image **302** to create segments. These segments may separate wiring harness **303** from the background. This separation facilitates identifying the wiring harness in camera image **302.**

[0083] Object detection **314** can include detecting specific objects in camera image **302.** These objects can be specific objects such as wiring harness **303** that convolutional neural network **300** has been trained to identify from image pixels in camera image **302.**

[0084] In this example, image classification **316** can be used to determine whether an anomaly is present in camera image **302.** In some cases, the classification can include no anomaly in addition to different types of anomalies. Further, image classification **316** can also be used for Image selection and labeling. The selection of

images and labeling can be used to create training datasets for training machine learning models to classify a type of anomaly in an image.

[0085] Object localization **318** can include detecting bounding boxes in camera image **302** that contains a specific object such as wiring harness **303**. In this example, convolutional neural network **300** has been trained to identify wiring harnesses.

[0086] With reference next to **Figure 4**, an illustration of anomaly detection using a machine learning model is depicted in accordance with an illustrative embodiment. As depicted in this example, anomaly detection can be performed using machine learning (ML) model **400**. In this example, machine learning model **400** performs computer vision (CV) based object recognition **403**.

[0087] In this example, machine learning model **400** receives image **402** as an input for analysis. In this example, machine learning model **400** identifies anomaly **404** and outputs image **407** with an enlarged view of image **402** showing anomaly **404**. In this example, anomaly **404** is indicated using anomaly bounding box **406**. In this example, machine learning model **400** performs this analysis and identification of anomaly **404** using computer vision-based object recognition that can include components such as those for object recognition **310** as illustrated in **Figure 3**.

[0088] Next in **Figure 5**, an illustration of machine learning model training is depicted in accordance with an illustrative embodiment. In this illustrative example, machine learning model **500** is implemented as wiring anomaly classifier **502**.

[0089] In this example, model training and validation **504** is performed on machine learning model **500** machine

learning model **500** to train machine learning model **500** to operate as wiring anomaly classifier **502**.

[0090] In this example, the training is performed using training dataset **506**. Training dataset **506** is comprised of augmented data **508** generated from images and synthetic data **510**. These types of data are used in addition to actual images to increase the amount of training data available for training machine learning model **500**.

[0091] The different illustrative examples provide an ability to generate additional images for training dataset **506** in a manner that increases the accuracy of machine learning model **500** operating as wiring anomaly classifier **502**. As depicted in this example, the images in augmented data **508** and synthetic data **510** are created in a manner that provides an increased number of images showing anomalies in a manner that increases the accuracy of machine learning model **500**.

[0092] In this illustrative example, detected anomaly images **512** can be identified and stored as anomaly images **514**. In this example, image data augmentation **516** can be performed on anomaly images **514** to create augmented images **517**. These augmented images are stored as augmented data **508**. In this illustrative example, augmentation of anomaly images **514** can include at least one of translating, rotating, scaling, or other types of manipulations of anomaly images **514**. As a result, the number of images that can be used for training machine learning model **500** can be increased by performing image data augmentation **516** on anomaly images **514**. By increasing the number of images in training dataset **506**, the performance of machine learning model **500** can be increased through increasing the size of training dataset **506**. In this example, augmented data **508** includes

anomaly images **514** and images generated from augmenting anomaly images **514**.

[0093] Additionally, the size of training dataset **506** can be increased through the use of synthetic data **510**. In this example, synthetic data **510** comprises images that are created and not based on actual images such as detected anomaly images **512**.

[0094] For example, synthetic data **510** can be created using anomalies in anomaly definitions **520** defined in engineering standard handbooks and computer-aided design (CAD) models **522**. These two sources of information can be used to create images that form synthetic data **510**. In this example, the identification of anomalies as defined in engineering standard handbooks and other sources can be used to add those anomalies in CAD models **522** or to generate images with the anomalies using CAD models **522**. CAD models **522** with anomalies based on anomaly definitions **520** can then be used to generate synthetic images **524** that form synthetic data **510**. In this example, snapshot images of CAD models **522** with anomalies can be taken from different orientations perspectives and can be generated to create synthetic images **524**. In this example, synthetic images **524** are synthetic wiring harness images **525** with anomalies **527**. These images are synthetic wiring anomaly images.

[0095] Further, anomaly definitions **520** can also include identifications of types of anomalies such as fold, wrinkle, scratch, light abrasion, broken bond circumferentially, conducted information, or other types of anomalies. These identifications can be used as labels when generating synthetic images **524** using CAD models **522**.

[0096] The illustration of training dataset generation in this example is provided as an example implementation

and not meant to limit the manner in which other illustrative examples can be implemented. For example, image data augmentation **516** can also be performed on synthetic images **524** to create additional images for augmented images **517** in addition to those created using anomaly images **514**. As another example, although not shown, the images and augmented data **508** and synthetic data **510** can include labels depending on the type of training used to train machine learning model **500**.

[0097] As a result, by using the anomaly types defined in anomaly definitions **520** is labels, machine learning model **500** can output classifications based on the anomaly types in anomaly definitions **520** after model training and validation **504** is performed using training dataset **506**. In this manner, classifications generated by machine learning model **500** can conform to desired definitions such as those used by industry, manufacturers, suppliers, airlines, or other organizations.

[0098] With reference next to **Figure 6** and **Figure 7**, illustrations of anomaly definitions are depicted in accordance with an illustrative embodiment. These two figures are examples of anomaly definitions **520** in **Figure 5**.

[0099] In this illustrative example, **Figure 6** is an illustration of wires and cables with anomalies depicted in accordance with an illustrative embodiment. In this illustrative example, illustrations **600** are examples of anomalies that can be used with computer-aided design models to generate synthetic images. As depicted, illustrations **600** show in detail types of anomalies that can occur on wires and cables. These details in illustrations **600** show anomaly types can be used to generate images of anomalies using computer-aided design models.

[00100] With reference to **Figure 7**, an illustration of a table wiring components and anomalies for wiring components are depicted with recommended dispositions in accordance with an illustrative embodiment. In this illustrative example, table **700** comprises columns in the form of wire component **702**, anomaly condition **704**, and recommended dispositions.

[00101] In another illustrative example, anomaly types can also be based on recommended dispositions **706**. For example, anomaly type can be replacement, use as is, insulation repair, or some other type of classification. In other illustrative examples, anomaly types can be correlated with recommended dispositions **706** to indicate maintenance, rework, or no action that may be performed on a wiring harness.

[00102] In this illustrative example, anomaly condition **704** can be used as labels for classifying synthetic images using illustrations such as illustrations **600** in **Figure 6** with computer-aided design models. In another illustrative example, anomaly types can also be based on recommended dispositions **706**. For example, anomaly type can be replacement, use as is, insulation repair, or some other type of classification. In other illustrative examples, anomaly types can be correlated with recommended dispositions **706** to indicate an action that that may be performed on a wiring harness.

[00103] Turning next to **Figure 8**, an illustration of a dataflow diagram for training machine learning model using a synthetic dataset is depicted in accordance with an illustrative embodiment. In this illustrative example, synthetic dataset **800** is an example of synthetic data **510** in **Figure 5** with labels.

[00104] As depicted, training dataset **810** can be used in performing machine learning (ML) model training **812** to

train machine learning model **804** to classify anomalies. In this example, the amount of training data in training dataset **810** can be increased by generating synthetic dataset **800** and adding those images in synthetic dataset **800** to training dataset **810**. In this example, synthetic dataset **800** can be generated using generative artificial intelligence (AI) model **802** and machine learning (ML) model **804**.

[00105] In this illustrative example, bounding box images **814** are images from within bounding boxes in training dataset **810**. In these examples, bounding box images **814** are images containing anomalies.

[00106] In this illustrative example, training dataset **810** is an example of training dataset **506** in **Figure 5**. As such, training dataset **810** can include images in the form of augmented data and synthetic data.

[00107] As depicted, generative AI model **802** generates synthetic wiring anomaly images **806** using bounding box images **814**. In this example, synthetic wiring anomaly images **806** are synthetic wiring harness images **831** with anomalies **833**.

[00108] Generative AI model **802** is a generative model from a generative adversarial network (GAN). Generative AI model **802** has been trained to generate synthetic wiring anomaly images **806**. Generative AI model **802** has been trained in the statistical distribution of data and learn knowledge about the data to generate synthetic wiring anomaly images **806**.

[00109] In this illustrative example, machine learning model **804** has been trained using training dataset **810** prior to beginning this dataflow. In this example, machine learning model **804** receives synthetic wiring anomaly images **806** as an input. Machine learning model **804** classifies these images to generate synthetic wiring

anomaly labels **808**. This classification involves detecting anomalies and classifying the anomalies in synthetic wiring anomaly images **806**.

[00110] In this example, join **820** associates synthetic wiring anomaly labels in weight with synthetic wiring anomaly images **806** to create synthetic dataset **800**.

[00111] In this example, synthetic dataset **800** is added to training dataset **810** to increase the amount of training data in training dataset **810**. With the addition of synthetic dataset **800** to training dataset **810**, machine learning model training **812** can be performed for machine learning model **804**. This further training with increased data in training dataset **810** can increase the accuracy of machine learning model **804**.

[00112] Numerous iterations of this process can be performed to increase the size of training dataset **810**. In this example, synthetic wiring anomaly labels and weight can be checked to determine the accuracy of machine learning model **804**. With analysis additional iterations of the process can be performed until satisfactory performance of machine learning model **804** occurs.

[00113] This dataflow in **Figure 8** illustrates one application of using a generative artificial intelligence model in which this model is used to create additional synthetic data in the form of synthetic wiring anomaly images **806**. Generative artificial intelligence model **802** can be trained with an existing dataset to create additional synthetic data (features only). In this example, synthetic wiring anomaly labels **808** are identified by machine learning model **804** that has been already trained for object detection. Thus, the synthetic wiring anomaly images containing features in the form of anomalies and the labels can be joined

together to create synthetic dataset **800** that is added to training dataset **810** to create a larger training dataset to train more accurate machine learning models.

[00114] With reference next to **Figure 9**, an illustration of a dataflow diagram using information from engineering standard handbooks to create computer-aided design models and actions for different anomalies is depicted in accordance with an illustrative embodiment. In this illustrative example, engineering standard handbook **900** can be a handbook for wiring and cable anomaly identification and remedial actions. In this illustrative example, information retrieval **902** can be performed to retrieve information on actions to be taken based on different wiring anomalies. This information can be used to create wiring anomaly action table **904**. This table can include information about actions to be taken with respect to wiring harnesses in which anomalies are identified. Further, anomaly selection and computer-aided design model creation **906** can be performed to create computer-aided design (CAD) models **908** containing anomalies. This creation of CAD models **908** can be performed using illustrations and descriptions of anomalies in engineering standard handbook **900**.

[00115] Turning next to **Figure 10**, an illustration of a dataflow diagram for performing actions to rework wiring harnesses is depicted in accordance with an illustrative embodiment. In this illustrative example, image **1000** includes anomaly **1002** within bounding box **1004**. This image is input into machine learning model **1005** that operates as wiring anomaly classifier **1006**. In this example, machine learning (ML) model **1005** operating as wiring anomaly classifier **1006** is an example of machine learning model **500** operating as wiring anomaly classifier

502 in **Figure 5**. This classifier can be trained using the same training dataset as depicted in **Figure 5**.

[00116] In this illustrative example, machine learning model **1005** output anomaly codes **1010**. These anomaly codes correspond to various classifications for anomalies. Anomaly codes **1010** can be text, numbers, alphanumeric strings, or take other forms.

[00117] In this illustrative example, anomaly codes **1010** can be used as an index into wiring anomaly action table **1012**. This table is an example of wiring anomaly action table **904** created from engineering standard handbook **900** in **Figure 9**. In this manner, an anomaly code can be used to identify an action in wiring anomaly action table **1012**. Based on the identification, one or more remedial actions **1014** can be performed as rework for the wiring harness in which one or more anomalies have been identified. The remedial action in some cases can be maintenance, rework, or no action. In this manner, the machine learning models used with mobile personal inspection devices such as handheld scanners can be used to identify anomalies in actual physical wiring harnesses such that then a remedial action can be performed.

[00118] With reference next to **Figure 11**, an illustration of a dataflow diagram for transfer learning of machine learning models for use in a handheld scanner is depicted in accordance with an illustrative embodiment. In this illustrative example, large machine learning (ML) models **1100** are located in cloud **1102**.

[00119] In this example, teacher-student transfer learning **1104** can be performed to create small machine learning (ML) models **1106** for use in handheld device **1108**. This type of transfer learning creates a machine learning model with sufficient performance that can run in handheld device **1108** to perform real-time inspections

that can include detecting anomalies and recommending remedial actions.

[00120] In this example, large ML models **1100** are machine learning models that have a size that cannot be run directly on handheld device **1108**. Small ML models **1106** have a small enough footprint to run on handheld device **1108**. Small machine learning models will have sufficient performance in detecting and classifying anomalies in wiring parts.

[00121] In this manner, handheld device **1108** can be used for real-time visual based wiring harness health inspection in the field. In this example, handheld device **1108** can be used as a stand-alone device without needing to send images back to large machine learning models **1100** in cloud **1102** for analysis.

[00122] In this manner, handheld device **1108** with one or more of small machine learning models **1106** have increased flexibility in performing wiring harness inspections. In this example, handheld device **1108** with a small machine learning model can perform real-time inspection, detection, and remedial action recommendation in the field under various conditions including those where a network or internet connection is unavailable.

[00123] Turning to **Figure 12**, an illustration of teacher-student transfer learning is depicted in accordance with an illustrative embodiment. In this illustrative example, teacher model **1200** is a pre-trained model. This pretrained machine learning model has been trained to detect anomalies in wiring harnesses. The detection of anomalies can also include classifying anomalies and may also include recommending remedial actions to be taken based on the classification of the anomaly.

[00124] In this illustrative example, student model **1202** is a machine learning model that is to be trained by teacher model **1200.** Student model **1202** has a smaller size than teacher model **1200.** Student model **1202** as the size selected to run on mobile computing devices such as handheld scanner **1204** and mobile phone **1206.**

[00125] In this example, the teacher-student transfer learning is also referred to as knowledge distillation **1208.**

[00126] In this example, teacher model **1200** processes training data **1212** and generates predictions **1214.** These predictions are considered soft labels using a softmax layer, which converts the output from teacher model **1200** into probabilities for predictions **1214.**

[00127] In this example, student model **1202** processes training data **1212** to generate predictions **1216.** In this example, student model **1202** learns to predict these softer probabilities in predictions **1214** rather than the original hard labels for training data **1212.**

[00128] This process enables student model **1202** to learn from the more expressive knowledge in teacher model **1200.** Further, this type of training enables student model **1202** to learn subtle patterns and relationships that normal labels use in training data **1212** may not convey.

[00129] In this example, predictions **1214** become ground truth **1218** that guides the student model **1202** during the training process. This type of training can provide a more informative and efficient transfer of knowledge and training student model **1202** to have desirable performance even though student model **1202** is smaller than teacher model **1200.**

[00130] By leveraging the predictions **1214** from teacher model **1200,** student model **1202** can benefit from learned

representations and generalization capabilities of teacher model **1200**. This type of knowledge transfer can enable student model **1202** to achieve comparable performance to teacher model **1200** even though student model **1202** is smaller in size. As result, knowledge distillation **1208** creates efficient machine learning models for deployment in resource-constrained environments such as in handheld scanner **1204** and mobile phone **1206**.

[00131] With reference next to **Figure 13**, an illustration of a feedback loop for machine learning model performance enhancement is depicted in accordance with an illustrative embodiment. In this illustrative example, machine learning model **1300** has been trained by model training and validation **1302** using training dataset **1304** in regular loop **1305**. In this example, training dataset **1304** comprises augmented data **1306** and synthetic data **1308**. In this example, training dataset **1304** with augmented data **1306** and synthetic data **1308** is an example of training dataset **506** with augmented data **508** and synthetic data **510** in **Figure 5**.

[00132] In this example, feedback loop **1307** can be used to perform additional training of machine learning model **1300**. In this example, handheld scanner **1320** generates images. These images can be stored with images **1322** generated by handheld scanner **1320** as well as other handheld scanners or mobile personal scanning devices. In this example, image selection and labeling **1324** can be performed for images **1322**. In this example, images **1322** can be for a particular aircraft fleet. In other words, images **1322** can be an aircraft fleet selected from a group comprising from a group comprising all aircraft operated by an organization, the aircraft of a same type, the aircraft on a same route, the aircraft with a same

cabin configuration, the aircraft within an age range, or other groupings of aircraft.

[00133] In this example, images selected from images **1322** can be images that can provide additional model performance enhancement for machine learning model **1300**. For example, the selection of images from images **1322** can include images of anomalies that show up for a particular fleet of aircraft for which scanning is performed by handheld scanner **1320** and mobile personal computing devices. Over time, images **1322** can be for wiring harnesses with anomalies in different areas of the aircraft in the fleet. In other words, wiring harnesses in some areas of an aircraft may have more anomalies over time than wiring harnesses in other areas. Further, particular types of anomalies may show up more often over time that are specific to a fleet of aircraft.

[00134] By selecting these images, machine learning model **1300** can be trained to better detect those areas in the fleet of aircraft for which handheld scanner **1320** is used.

[00135] In this example, the selected images from images **1322** are labeled by image selection and labeling **1324** to form labeled images **1326**. In this example, labeled images **1326** can be processed by image data augmentation **1328** to generate augmented images for augmented data **1306**. In this manner, new data can be added to training dataset **1304** or used in training machine learning model **1300**. Further, labeled images **1326** can also be used by model training and validation **1302** along with training dataset **1304** to train further machine learning model **1300**.

[00136] The illustration of this feedback loop is an example of one manner in which a machine learning model can be iteratively or continuously trained to improve

performance. This illustration is not meant to limit the manner in which other illustrative examples can be implemented. For example, labeled images **1326** can be considered part of training dataset **1304** in some illustrative examples.

[00137] With reference now to **Figure 14**, an illustration of a data flow diagram for image augmentation is depicted in accordance with an illustrative embodiment. In this illustrative example, image dataset **1400** can be processed in a number of different ways to generate image dataset **1400** and augmented image dataset **1402**.

[00138] For example, images from image dataset **1400** can be selected using manual selection **1404** or automatic selection by train machine learning (ML) models **1406**. In this example, the selected images are images with identified anomaly zones **1408**, that can be augmented to create additional images for training data.

[00139] In this example, defect zone resizing, rotation, and translation **1410** can be performed upon the images selected for augmentation. At least one of these types of changes to the images or any combination of these changes can be used to create augmented images for augmented image dataset **1402**. These images in augmented image dataset **1402** can be examples of augmented data **508** in **Figure 5**.

[00140] With reference next to **Figure 15**, an illustration of a data flow diagram for labeling and parameter extraction is depicted in accordance with an illustrative embodiment. In this illustrative example, wiring harness images **1500** are images captured by a camera. In this depicted example, manual annotation **1502** can be performed on wiring harness images to form labeled

training dataset **1504** for use in machine learning (ML) model training **1506**.

[00141] Further in this example, image scene analysis **1508** can be performed on wiring harness images **1500** to obtain parameters **1510** for wiring harness images **1500**. Parameters **1510** can be at least one of geometry or material of objects in the image. This analysis can be performed using an artificial intelligence model.

[00142] In this example, these parameters can be used in computer-aided design (CAD) model creation **1512** or synthetic image creation **1514** using generative artificial intelligence models.

[00143] Next in **Figure 16**, an illustration of a data flow diagram for synthetic image generation is depicted in accordance with an illustrative embodiment. In this example, generative artificial intelligence model **1600** is an example of an artificial intelligence model that can be used to generate parameters **1602** for use in creating images for synthetic data.

[00144] In this example, parameters **1602** such as the geometry and material of objects in the image and the detail information of the wiring defects such as types, sizes, or orientations are input into generative AI model **1600** with the output parameter being added to parameters **1602** to create a larger set of parameters **1602**.

[00145] In this example, generative AI model **1600** learns the statistical distribution of the parameters. Statistical distribution can be used to expand the training dataset by creating a larger parameter set with similar or same statistical distribution. As a result, the resulting larger training dataset can help to improve the accuracy of the trained machine learning models. In this example, the larger training dataset takes the form of labeled synthetic images **1606**.

[00146] In this example, parameters **1602** can be used as inputs into computer-aided design (CAD) software **1603** to at least one of create or modify computer-aided design models **1604**. In this example, snapshots **1608** can be created from computer aided design models **1604**. In this example, snapshots **1608** can be taken from computer aided design models **1604** at different angles, at different distances, with different lighting conditions, or by simulating various camera settings. Since the images are created from scenes with known wiring anomaly conditions, labels can be automatically added to snapshots **1608 of** created images without additional processing or manual data labeling to generate labeled synthetic images **1606**.

[00147] In this example, labeled synthetic images **1606** can be images with or without wiring anomalies. These images can be labeled to indicate whether anomalies are present. Also, labels can be added for the type of anomaly. Thus, generative artificial intelligence models can be used to increase the size of training datasets through creating parameters **1602** based on statistical distributions and by creating synthetic wiring anomaly images.

[00148] Turning next to **Figure 17**, an illustration of a flowchart of a process for inspecting a wiring harness in an aerospace vehicle is depicted in accordance with an illustrative embodiment. The process in **Figure 17** can be implemented in hardware, software, or both. When implemented in software, the process can take the form of program instructions that are run by one of more processor units located in one or more hardware devices in one or more computer systems. For example, the process can be implemented in inspection manager **214** in computer system **212** in **Figure 2**.

[00149] The process begins by controlling a camera system to generate a set of images of the wiring harness in the vehicle, wherein the camera system is connected to the mobile personal computing device (operation **1700**). The process sends the set of images of the wiring harness to a machine learning model, wherein the machine learning model is trained to detect anomalies in a set of images of a wiring harness in an aerospace vehicle (operation **1702**).

[00150] The process receives a result from the machine learning model indicating whether an anomaly is present in the wiring harness in the aerospace vehicle (operation **1704**). The process terminates thereafter.

[00151] With reference now to **Figure 18**, an illustration of a flowchart of a process for creating training data is depicted in accordance with an illustrative embodiment. The training data in this example can be used to train machine learning models to be more specific in identifying anomalies in a particular fleet of aircraft. The process in this example is an example of additional operations that can be performed with the operations in **Figure 17**.

[00152] The process begins by storing images captured by a set of mobile personal computing devices in which storing the images captured from a set of mobile personal computing devices forms stored images (operation **1800**). The process stores classifications of the anomalies identified in the images by the set of mobile personal computing devices in association with the stored images (operation **1802**).

[00153] The process selects images from the stored images in which selecting the images forms selected images (operation **1804**). Next, the process labels the selected images with labels based on the classification

of the anomalies for the selected images (operation **1806**).

[00154] The process performs additional training of the machine learning model using the selected images with the labels (operation **1808**). The process terminates thereafter.

[00155] Thus, these images can be used to train the machine learning model over time to identify anomalies for a specific fleet of aircraft. This process uses a feedback loop that can be performed periodically or continuously. The images can be for an aircraft fleet operated by an organization in which the additional training of the machine learning model increases the accuracy of the machine learning model in detecting anomalies for the aircraft fleet. The organization can be selected from a group comprising an airline, a government, and an aircraft manufacturer.

[00156] With reference to **Figure 19**, an illustration of a flowchart of process for selecting images is depicted in accordance with an illustrative embodiment. The process depicted in this flowchart is an example of an implementation for operation **1804** in **Figure 18**.

[00157] The process selects images having anomalies identified in an aircraft fleet in which selecting the images forms selected images, wherein the additional training of the machine learning model results in the machine learning model having increased accuracy in detecting anomalies in the wiring harnesses for the aircraft fleet (operation **1900**). The process terminates thereafter. The selection of images for anomalies in an aircraft fleet can result in the machine learning model becoming fleet specific for an airline or other organization. In one illustrative example, the aircraft fleet can be selected from a group comprising all

aircraft operated by an organization, the aircraft of a same type, the aircraft on a same route, the aircraft with a same cabin configuration, or the aircraft within an age range.

[00158] Turning now to **Figure 20**, an illustration of a flowchart of a process for generating training data is depicted in accordance with an illustrative embodiment. The process illustrated in this figure is an example of additional operations that can be performed with the operations in **Figure 17**. This process can be used to generate synthetic data from computer-aided design models and real images of wiring harnesses.

[00159] The process begins by generating the first synthetic wiring harness images with the anomalies using a computer-aided design model of wiring harnesses and the anomalies defined by engineering standards (operation **2000**). The process generates second synthetic wiring harness images with the anomalies using real images of the wiring harnesses with the anomalies (operation **2002**).

[00160] The process classifies the first synthetic wiring harness images and the second synthetic wiring harness images in which the classifying forms labels for the first synthetic wiring harness images and second synthetic wiring harness images (operation **2004**). The process adds the first synthetic wiring harness images and second synthetic wiring harness images with the labels to a training dataset (operation **2006**). The process terminates thereafter.

[00161] Next in **Figure 21**, an illustration of a flowchart of a process for generating training data is depicted in accordance with an illustrative embodiment. The process illustrated in this figure is an example of additional operations that can be performed with the operations in **Figure 17**.

[00162] The process begins by creating synthetic wiring harness images using a second machine learning model trained to generate synthetic wiring harness images from wiring harness images in training dataset (operation **2100**). The process determines whether the synthetic wiring harness images have the anomalies (operation **2102**). The process adds labels to the synthetic wiring harness images to indicate whether the anomalies are present (operation **2104**). In this example, the synthetic wiring harness images with the anomalies are synthetic wiring anomaly images;

[00163] The process stores the synthetic wiring harness images with the labels to create a synthetic training dataset (operation **2106**). The process terminates thereafter.

[00164] In this depicted example, the second machine learning model can be a generative artificial intelligence model. This model can be previously trained in a generative adversarial network to create synthetic wiring harness images using wiring harness images.

[00165] In **Figure 22**, an illustration of a flowchart of a process for training a machine learning model for use in a mobile personal computing device is depicted in accordance with an illustrative embodiment. In this illustrative example, the mobile personal computing device may have limited computing resources as compared to a workstation or server computer.

[00166] The process trains a student machine learning model using a teacher machine learning model in which the student machine learning model is the machine learning model and is smaller in size than the teacher machine learning model, wherein the teacher machine learning model has been trained to detect the anomalies in images

of wiring harnesses (operation **2200**). The process terminates thereafter.

[00167] Turning now to **Figure 23**, an illustration of a flowchart of a process for performing a remedial action is depicted in accordance with an illustrative embodiment. The process illustrated in this figure is an example of an additional operation that can be performed with the operations in **Figure 17**.

[00168] The process begins by identifying a remedial action in response to the results indicating the presence of the anomalies in the wiring harness (operation **2300**). In operation **2300**, the remedial action can be identified in a number of different ways. For example, the machine learning model can include remedial action. As result, the remedial actions be identified from result returns from the machine learning model.

[00169] In another illustrative example, the indication of the anomaly in the result can also include a classification of the anomaly. This classification can be used to identify the remedial action.

[00170] In some cases, the classification may be based on classifications in anomaly definitions from handbooks for wire and cable damage and repairs and may include anomaly codes that can be used to identify remedial actions. With the use of anomaly codes identified from anomaly definitions in engineering standard handbooks, the remedial action can be determined based on information from those engineering standard handbooks.

[00171] The process performs the remedial action on the wiring harness (operation **2302**). The process terminates thereafter. In operation **2302**, remedial action is performed on the actual physical wiring harness in the aerospace vehicle. The remedial action can be, for

example, maintenance, replacement, logging the anomaly, or some other suitable action.

[00172] The flowcharts and block diagrams in the different depicted embodiments illustrate the architecture, functionality, and operation of some possible implementations of apparatuses and methods in an illustrative embodiment. In this regard, each block in the flowcharts or block diagrams can represent at least one of a module, a segment, a function, or a portion of an operation or step. For example, one or more of the blocks can be implemented as program instructions, hardware, or a combination of the program instructions and hardware. When implemented in hardware, the hardware can, for example, take the form of integrated circuits that are manufactured or configured to perform one or more operations in the flowcharts or block diagrams. When implemented as a combination of program instructions and hardware, the implementation may take the form of firmware. Each block in the flowcharts or the block diagrams can be implemented using special purpose hardware systems that perform the different operations or combinations of special purpose hardware and program instructions run by the special purpose hardware.

[00173] In some alternative implementations of an illustrative embodiment, the function or functions noted in the blocks may occur out of the order noted in the figures. For example, in some cases, two blocks shown in succession may be performed substantially concurrently, or the blocks may sometimes be performed in the reverse order, depending upon the functionality involved. Also, other blocks may be added in addition to the illustrated blocks in a flowchart or block diagram.

[00174] Turning now to **Figure 24**, a block diagram of a data processing system is depicted in accordance with an

illustrative embodiment. Data processing system **2400** can be used to implement server computer **104**, server computer **106**, or client devices **110** in **Figure 1**. In this illustrative example, data processing system **2400** includes communications framework **2402**, which provides communications between processor unit **2404**, memory **2406**, persistent storage **2408**, communications unit **2410**, input/output (I/O) unit **2412**, and display **2414**. In this example, communications framework **2402** takes the form of a bus system.

[00175] Processor unit **2404** serves to execute instructions for software that can be loaded into memory **2406**. Processor unit **2404** includes one or more processors. For example, processor unit **2404** can be selected from at least one of a multicore processor, a central processing unit (CPU), a graphics processing unit (GPU), a physics processing unit (PPU), a digital signal processor (DSP), a network processor, or some other suitable type of processor. Further, processor unit **2404** can be implemented using one or more heterogeneous processor systems in which a main processor is present with secondary processors on a single chip. As another illustrative example, processor unit **2404** can be a symmetric multi-processor system containing multiple processors of the same type on a single chip.

[00176] Memory **2406** and persistent storage **2408** are examples of storage devices **2416**. A storage device is any piece of hardware that is capable of storing information, such as, for example, without limitation, at least one of data, program instructions in functional form, or other suitable information either on a temporary basis, a permanent basis, or both on a temporary basis and a permanent basis. Storage devices **2416** may also be referred to as computer readable storage devices in these

illustrative examples. Memory **2406**, in these examples, can be, for example, a random-access memory or any other suitable volatile or non-volatile storage device. Persistent storage **2408** may take various forms, depending on the particular implementation.

[00177] For example, persistent storage **2408** may contain one or more components or devices. For example, persistent storage **2408** can be a hard drive, a solid-state drive (SSD), a flash memory, a rewritable optical disk, a rewritable magnetic tape, or some combination of the above. The media used by persistent storage **2408** also can be removable. For example, a removable hard drive can be used for persistent storage **2408**.

[00178] Communications unit **2410**, in these illustrative examples, provides for communications with other data processing systems or devices. In these illustrative examples, communications unit **2410** is a network interface card.

[00179] Input/output unit **2412** allows for input and output of data with other devices that can be connected to data processing system **2400**. For example, input/output unit **2412** may provide a connection for user input through at least one of a keyboard, a mouse, or some other suitable input device. Further, input/output unit **2412** may send output to a printer. Display **2414** provides a mechanism to display information to a user.

[00180] Instructions for at least one of the operating system, applications, or programs can be located in storage devices **2416**, which are in communication with processor unit **2404** through communications framework **2402**. The processes of the different embodiments can be performed by processor unit **2404** using computer-implemented instructions, which may be located in a memory, such as memory **2406**.

[00181] These instructions are referred to as program instructions, computer usable program instructions, or computer readable program instructions that can be read and executed by a processor in processor unit **2404.** The program instructions in the different embodiments can be embodied on different physical or computer readable storage media, such as memory **2406** or persistent storage **2108.**

[00182] Program instructions **2418** are located in a functional form on computer readable media **2420** that is selectively removable and can be loaded onto or transferred to data processing system **2400** for execution by processor unit **2404.** Program instructions **2418** and computer readable media **2420** form computer program product **2422** in these illustrative examples. In the illustrative example, computer readable media **2420** is computer readable storage media **2424.**

[00183] Computer readable storage media **2424** is a physical or tangible storage device used to store program instructions **2418** rather than a medium that propagates or transmits program instructions **2418.** Computer readable storage media **2424** may be at least one of an electronic storage medium, a magnetic storage medium, an optical storage medium, an electromagnetic storage medium, a semiconductor storage medium, a mechanical storage medium, or other physical storage medium. Some known types of storage devices that include these mediums include: a diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), a static random access memory (SRAM), a compact disc read-only memory (CD-ROM), a digital versatile disk (DVD), a memory stick, a floppy disk, a mechanically encoded device, such as

punch cards or pits / lands formed in a major surface of a disc, or any suitable combination thereof.

[00184] Computer readable storage media **2424**, as that term is used in the present disclosure, is not to be construed as storage in the form of transitory signals per se, such as at least one of radio waves or other freely propagating electromagnetic waves, electromagnetic waves propagating through a waveguide, light pulses passing through a fiber optic cable, electrical signals communicated through a wire, or other transmission media.

[00185] Further, data can be moved at some occasional points in time during normal operations of a storage device. These normal operations include access, de-fragmentation or garbage collection. However, these operations do not render the storage device as transitory because the data is not transitory while the data is stored in the storage device.

[00186] Alternatively, program instructions **2418** can be transferred to data processing system **2400** using a computer readable signal media. The computer readable signal media are signals and can be, for example, a propagated data signal containing program instructions **2418**. For example, the computer readable signal media can be at least one of an electromagnetic signal, an optical signal, or any other suitable type of signal. These signals can be transmitted over connections, such as wireless connections, optical fiber cable, coaxial cable, a wire, or any other suitable type of connection.

[00187] Further, as used herein, "computer readable media **2420**" can be singular or plural. For example, program instructions **2418** can be located in computer readable media **2420** in the form of a single storage device or system. In another example, program instructions **2418** can be located in computer readable

media **2420** that is distributed in multiple data processing systems. In other words, some instructions in program instructions **2418** can be located in one data processing system while other instructions in program instructions **2418** can be located in one data processing system. For example, a portion of program instructions **2118** can be located in computer readable media **2420** in a server computer while another portion of program instructions **2418** can be located in computer readable media **2420** located in a set of client computers.

[00188] The different components illustrated for data processing system **2400** are not meant to provide architectural limitations to the manner in which different embodiments can be implemented. In some illustrative examples, one or more of the components may be incorporated in, or otherwise form a portion of, another component. For example, memory **2406**, or portions thereof, may be incorporated in processor unit **2404** in some illustrative examples. The different illustrative embodiments can be implemented in a data processing system including components in addition to or in place of those illustrated for data processing system **2400**. Other components shown in **Figure 24** can be varied from the illustrative examples shown. The different embodiments can be implemented using any hardware device or system capable of running program instructions **2418**.

[00189] Illustrative embodiments of the disclosure may be described in the context of aircraft manufacturing and service method **2500** as shown in **Figure 25** and aircraft **2600** as shown in **Figure 26**. Turning first to **Figure 25**, an illustration of an aircraft manufacturing and service method is depicted in accordance with an illustrative embodiment. During pre-production, aircraft manufacturing and service method **2500** may include

specification and design **2502** of aircraft **2600** in **Figure 26** and material procurement **2504.**

[00190] During production, component and subassembly manufacturing **2506** and system integration **2508** of aircraft **2600** in **Figure 26** takes place. Thereafter, aircraft **2600** in **Figure 26** can go through certification and delivery **2510** in order to be placed in service **2512.** While in service **2512** by a customer, aircraft **2600** in **Figure 26** is scheduled for routine maintenance and service **2514,** which may include modification, reconfiguration, refurbishment, and other maintenance or service.

[00191] Each of the processes of aircraft manufacturing and service method **2500** may be performed or carried out by a system integrator, a third party, an operator, or some combination thereof. In these examples, the operator may be a customer. For the purposes of this description, a system integrator may include, without limitation, any number of aircraft manufacturers and major-system subcontractors; a third party may include, without limitation, any number of vendors, subcontractors, and suppliers; and an operator may be an airline, a leasing company, a military entity, a service organization, and so on.

[00192] With reference now to **Figure 26,** an illustration of an aircraft is depicted in which an illustrative embodiment may be implemented. In this example, aircraft **2600** is produced by aircraft manufacturing and service method **2500** in **Figure 25** and may include airframe **2602** with plurality of systems **2604** and interior **2606.** Examples of systems **2604** include one or more of propulsion system **2608,** electrical system **2610,** hydraulic system **2612,** and environmental system **2614.** Any number of other systems may be included.

Although an aerospace example is shown, different illustrative embodiments may be applied to other industries, such as the automotive industry.

[00193] Apparatuses and methods embodied herein may be employed during at least one of the stages of aircraft manufacturing and service method **2500** in **Figure 25.**

[00194] In one illustrative example, components or subassemblies produced in component and subassembly manufacturing **2506** in **Figure 25** can be fabricated or manufactured in a manner similar to components or subassemblies produced while aircraft **2600** is in service **2512** in **Figure 25.** As yet another example, one or more apparatus embodiments, method embodiments, or a combination thereof can be utilized during production stages, such as component and subassembly manufacturing **2506** and system integration **2508** in **Figure 25.** One or more apparatus embodiments, method embodiments, or a combination thereof may be utilized while aircraft **2600** is in service **2512,** during maintenance and service **2514** in **Figure 25,** or both. The use of a number of the different illustrative embodiments may substantially expedite the assembly of aircraft **2600,** reduce the cost of aircraft **2600,** or both expedite the assembly of aircraft **2600** and reduce the cost of aircraft **2600.**

[00195] For example, wiring harness inspection system **202** in **Figure 2** can be used during at least one of component and subassembly manufacturing **2506** or system integration **2508** to inspect wiring harnesses as the harnesses are manufactured and integrated into aircraft **2600.** In another example, this wiring harness inspection system can also be used during maintenance and service **2514** to inspect wiring harnesses. Maintenance and service **2514** can be routine maintenance and service,

which may include modification, reconfiguration, refurbishment, and other maintenance or service.

[00196] Some features of the illustrative examples are described in the following clauses. These clauses are examples of features and are not intended to limit other illustrative examples.

[00197] Clause 1

[00198] An aerospace wiring harness inspection system comprising:

[00199] a mobile personal computing device;

[00200] a camera system connected to the mobile personal computing device;

[00201] a machine learning model running in the mobile personal computing device, wherein the machine learning model is trained to detect anomalies in a set of images of a wiring harness in an aerospace vehicle; and

[00202] an inspection manager configured to:

[00203] control the camera system to generate a set of images of the wiring harness;

[00204] send the set of images of the wiring harness to the machine learning model; and

[00205] receive a result from the machine learning model indicating whether an anomaly is present in the wiring harness.

[00206] Clause 2

[00207] The aerospace wiring harness inspection system according to clause 1 further comprising:

[00208] a computer system configured to:

[00209] store images captured by a set of mobile personal computing devices in which storing the images captured from a set of mobile personal computing devices forms stored images;

[00210] store classifications of the anomalies identified in the images by the set of mobile personal computing devices in association with the stored images;

[00211] select images from the stored images in which selecting the images forms selected images;

[00212] label the selected images with labels based on the classifications of the anomalies for the selected images; and

[00213] perform additional training of the machine learning model using the selected images with the labels.

[00214] Clause 3

[00215] The aerospace wiring harness inspection system according to clause 2, where the images are for an aircraft fleet operated by an organization, wherein the additional training of the machine learning model increases an accuracy of the machine learning model in detecting the anomalies for the aircraft fleet.

[00216] Clause 4

[00217] The aerospace wiring harness inspection system according to clause 3, wherein the organization is selected from a group comprising an airline, a government, and an aircraft manufacturer.

[00218] Clause 5

[00219] 5. The aerospace wiring harness inspection system according one of clauses 1 or 2, wherein in selecting the images, the computer system is configured to:

[00220] select images having the anomalies identified in an aircraft fleet in which selecting the images forms selected images, wherein the additional training of the machine learning model results in the machine learning model having increased accuracy in detecting the anomalies in wiring harnesses for the aircraft fleet.

[00221] Clause 6

[00222] The aerospace wiring harness inspection system according to clause 5, wherein the aircraft fleet is selected from a group comprising all aircraft operated by an organization, the aircraft of a same type, the aircraft on a same route, the aircraft with a same cabin configuration, or the aircraft within an age range.

[00223] Clause 7

[00224] The aerospace wiring harness inspection system according one of clauses 1, 2, 3, 4, 5, or 6 further comprising:

[00225] a computer system configured to:

[00226] generate first synthetic wiring harness images with the anomalies using computer-aided design models of wiring harnesses and the anomalies defined by engineering standards;

[00227] generate second synthetic wiring harness images with the anomalies using real images of the wiring harnesses with the anomalies;

[00228] classify the first synthetic wiring harness images and the second synthetic wiring harness images in which classifying forms labels for the first synthetic wiring harness images and the second synthetic wiring harness images;

[00229] add the first synthetic wiring harness images and the second synthetic wiring harness images with the labels to a training dataset; and

[00230] train the machine learning model using the synthetic training dataset.

[00231] Clause 8

[00232] The aerospace wiring harness inspection system according to one of clauses 1, 2, 3, 4, 5, 6, or 7 further comprising:

[00233] a computer system configured to:

[00234] create synthetic wiring harness images using a second machine learning model trained to generate the synthetic wiring harness images from wiring harness images in training dataset;

[00235] determine whether the synthetic wiring harness images have the anomalies;

[00236] add labels to the synthetic wiring harness images to indicate whether the anomalies are present, wherein the synthetic wiring harness images with the anomalies are synthetic wiring anomaly images;

[00237] store the synthetic wiring harness images with the labels to create a synthetic training dataset; and

[00238] train the machine learning model using the synthetic training dataset.

[00239] Clause 9

[00240] The aerospace wiring harness inspection system according to clause 8, wherein the second machine learning model is a generative artificial intelligence model trained in a generative adversarial network to create the synthetic wiring harness images using wiring harness images.

[00241] Clause 10

[00242] The aerospace wiring harness inspection system of according to one of clauses 1, 2, 3, 4, 5, 6, 7, 8, or 9 comprising:

[00243] a teacher machine learning model that has been trained to detect the anomalies in the images of wiring harnesses; and

[00244] a computer system configured to:

[00245] train a student machine learning model using the teacher machine learning model in which the student machine learning model is the machine learning model and

is smaller in size than the teacher machine learning model.

[00246] Clause 11

[00247] The aerospace wiring harness inspection system according to one of clauses 1, 2, 3, 4, 5, 6, 7, 8, 9, or 10, wherein the mobile personal computing device is selected from a group comprising an extension rod, a handheld scanner, a smart phone, a mobile phone, a tablet, smart glasses, augmented reality goggles, a laptop computer, and a smart watch.

[00248] Clause 12

[00249] The aerospace wiring harness inspection system according to one of clauses 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or 11, wherein the aerospace vehicle is selected from a group comprising an aircraft, a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a spacecraft, a jet aircraft, and a space shuttle.

[00250] Clause 13

[00251] A platform wiring inspection system comprising:

[00252] a mobile personal computing device;

[00253] a camera system connected to the mobile personal computing device;

[00254] a machine learning model running in the mobile personal computing device, wherein the machine learning model is trained to detect anomalies in images of wiring harnesses for a platform; and

[00255] an inspection manager configured to:

[00256] control the camera system to generate a set of images of a wiring harness;

[00257] send the set of images of the wiring harness to the machine learning model; and

[00258] receive a result from the machine learning model indicating whether an anomaly is present in the wiring harness.

[00259] Clause 14

[00260] The platform wiring inspection system according to clause 13, wherein the platform is selected from a group comprising a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, an aircraft, a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, and a building.

[00261] Clause 15

[00262] A method for inspecting a wiring harness in an aerospace vehicle, the method comprising:

[00263] controlling, by a computer system, a camera system to generate a set of images of the wiring harness in the aerospace vehicle, wherein the camera system is connected to a mobile personal computing device;

[00264] sending, by the computer system, the set of images of the wiring harness to a machine learning model, wherein the machine learning model is trained to detect anomalies in a set of images of the wiring harness in the aerospace vehicle; and

[00265] receiving, by the computer system, a result from the machine learning model indicating whether an anomaly is present in the wiring harness in the aerospace vehicle.

[00266] Clause 16

[00267] The method of according to clause 15 further comprising:

[00268] storing, by the computer system, images captured by a set of mobile personal computing devices in which storing the images captured from a set of mobile personal computing devices forms stored images;

[00269] storing, by the computer system, classifications of the anomalies identified in the images by the set of mobile personal computing devices in association with the stored images;

[00270] selecting, by the computer system, images from the stored images in which selecting the images forms selected images;

[00271] labeling, by the computer system, the selected images with labels based on the classifications of the anomalies for the selected images; and

[00272] performing, by the computer system, additional training of the machine learning model using the selected images with the labels.

[00273] Clause 17

[00274] The method according to clause 16, wherein the images are for an aircraft fleet operated by an organization, wherein the additional training of the machine learning model increases accuracy of the machine learning model in detecting the anomalies for the aircraft fleet.

[00275] Clause 18

[00276] The method according to clause 17, wherein the organization is selected from a group comprising an airline, a government, and an aircraft manufacturer.

[00277] Clause 19

[00278] The method according to clause 16, 17 or 18, wherein selecting the images comprises:

[00279] selecting, by the computer system, images having the anomalies identified in the aircraft fleet in which selecting the images forms selected images, wherein the additional training of the machine learning model results in the machine learning model having increased accuracy in detecting the anomalies in wiring harnesses for the aircraft fleet.

[00280] Clause 20

[00281] The method according to clause 19, wherein the aircraft fleet is selected from a group comprising all aircraft operated by the organization, the aircraft of a same type, the aircraft on a same route, the aircraft with a same cabin configuration, or the aircraft within an age range.

[00282] Clause 21

[00283] The method according to one of clauses 15, 16, 17, 18, 19, or 20 further comprising:

[00284] generating, by the computer system, first synthetic wiring harness images with the anomalies using computer-aided design models of wiring harnesses and the anomalies defined by engineering standards;

[00285] generating, by the computer system, second synthetic wiring harness images with the anomalies using real images of the wiring harnesses with the anomalies;

[00286] classifying, by the computer system, the first synthetic wiring harness images and the second synthetic wiring harness images in which classifying forms labels for the first synthetic wiring harness images and the second synthetic wiring harness images; and

[00287] adding, by the computer system, the first synthetic wiring harness images and the second synthetic wiring harness images with the labels to a training dataset.

[00288] Clause 22

[00289] The method according to one of clauses 15, 16, 17, 18, 19, 20, or 21 further comprising:

[00290] creating, by the computer system, synthetic wiring harness images using a second machine learning model trained to generate the synthetic wiring harness images from wiring harness images in a training dataset;

[00291] determining, by the computer system, whether the synthetic wiring harness images have the anomalies;

[00292] adding, by the computer system, labels to the synthetic wiring harness images to indicate whether the anomalies are present, wherein the synthetic wiring harness images with the anomalies are synthetic wiring anomaly images; and

[00293] storing, by the computer system, the synthetic wiring harness images with the labels to create a synthetic training dataset.

[00294] Clause 23

[00295] The method according to clause 22, wherein the second machine learning model is a generative artificial intelligence model trained in a generative adversarial network to create the synthetic wiring harness images using wiring harness images.

[00296] Clause 24

[00297] The method according to one of clauses 15, 16, 17, 18, 19, 20, 21, 22, or 23 further comprising:

[00298] training a student machine learning model using a teacher machine learning model in which the student machine learning model is the machine learning model and is smaller in size than the teacher machine learning model, wherein the teacher machine learning model has

been trained to detect the anomalies in the images of wiring harnesses.

[00299] Clause 25

[00300] The method according to one of clauses 15, 16, 17, 18, 19, 20, 21, 22, 23, or 24 further comprising:

[00301] identifying, by the computer system, a remedial action in response to the result indicating a presence of the anomaly in the wiring harness; and

[00302] performing the remedial action on the wiring harness.

[00303] Clause 26

[00304] The method according to one of clauses 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, or 25, wherein the mobile personal computing device is selected from a group comprising an extension rod, a handheld scanner, a smart phone, a mobile phone, a tablet, smart glasses, augmented reality goggles, a laptop computer, and a smart watch.

[00305] Clause 27

[00306] The method according to one of clauses 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25 or 26 , wherein the aerospace vehicle is selected from a group comprising an aircraft, a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a spacecraft, a jet aircraft, and a space shuttle.

[00307] Thus, the different illustrative examples provide a method, apparatus, system, and computer program product that can be used to inspect wiring harnesses and platforms such as aerospace vehicles. In one illustrative example, an aerospace wiring harness inspection system comprising a mobile personal computing device, a camera system connected to the mobile personal computing device, a machine learning model running in the

mobile personal computing device, and a controller. The machine learning model is trained to detect anomalies in a set of images of a wiring harness in an aerospace vehicle. The controller configured to control the camera system to generate a set of images of the wiring harness send the set of images of the wiring harness to the machine learning model and receive a result from the machine learning model indicating whether an anomaly is present in the wiring harness.

[00308] The use of the aerospace wiring harness inspection system can result in identifying anomalies in wiring harnesses more efficiently as compared to current techniques. The use of machine learning models with specialized training datasets and training operations for training machine learning models that focus on wiring harnesses for aerospace vehicles can result in increased efficiency in identifying anomalies. In the different illustrative examples, the training datasets can be generated in a manner that provides increased amounts of training data for training machine learning models to identify wiring harness anomalies.

[00309] Further, with the use of feedback loops and continued training machine learning models, the aerospace wiring harness inspection system can have increasing accuracy in identifying anomalies. This increasing accuracy can be focused on specific aircraft fleets through the use of the system on those specific aircraft leads. Further, by continuing to train machine learning models based on images from those aircraft fleets, the machine learning models can more efficiently and accurately identify anomalies that occur over time that are specific to those aircraft fleets.

[00310] Additionally, the aerospace wiring harness inspection system can be implemented in mobile personal

computing devices such as handheld scanners, mobile phones, smart glasses, and other devices. In these illustrative examples, the machine learning models can be created for use in these mobile personal computing devices such that the mobile computing devices can act as standalone devices without needing to send images to another location for analysis.

[00311] The description of the different illustrative embodiments has been presented for purposes of illustration and description and is not intended to be exhaustive or limited to the embodiments in the form disclosed. The different illustrative examples describe components that perform actions or operations. In an illustrative embodiment, a component can be configured to perform the action or operation described. For example, the component can have a configuration or design for a structure that provides the component an ability to perform the action or operation that is described in the illustrative examples as being performed by the component. Further, to the extent that terms "includes", "including", "has", "contains", and variants thereof are used herein, such terms are intended to be inclusive in a manner similar to the term "comprises" as an open transition word without precluding any additional or other elements.

[00312] Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different illustrative embodiments may provide different features as compared to other desirable embodiments. The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various

modifications as are suited to the particular use contemplated.

CLAIMS:

1. An aerospace wiring harness inspection system comprising:

a mobile personal computing device;

a camera system connected to the mobile personal computing device;

a machine learning model running in the mobile personal computing device, wherein the machine learning model is trained to detect anomalies in a set of images of a wiring harness in an aerospace vehicle; and

an inspection manager configured to:

control the camera system to generate a set of images of the wiring harness;

send the set of images of the wiring harness to the machine learning model; and

receive a result from the machine learning model indicating whether an anomaly is present in the wiring harness.

2. The aerospace wiring harness inspection system of claim 1 further comprising:

a computer system configured to:

store images captured by a set of mobile personal computing devices in which storing the images captured from a set of mobile personal computing devices forms stored images;

store classifications of the anomalies identified in the images by the set of mobile personal computing devices in association with the stored images;

select images from the stored images in which selecting the images forms selected images;

label the selected images with labels based on the classifications of the anomalies for the selected images; and

perform additional training of the machine learning model using the selected images with the labels.

3. The aerospace wiring harness inspection system of claim 2, where the images are for an aircraft fleet operated by an organization, wherein the additional training of the machine learning model increases an accuracy of the machine learning model in detecting the anomalies for the aircraft fleet.

4. The aerospace wiring harness inspection system of claim 2 or 3, wherein in selecting the images, the computer system is configured to:

select images having the anomalies identified in an aircraft fleet in which selecting the images forms selected images, wherein the additional training of the machine learning model results in the machine learning model having increased accuracy in detecting the anomalies in wiring harnesses for the aircraft fleet.

5. The aerospace wiring harness inspection system of claim 4, wherein the aircraft fleet is selected from a group comprising all aircraft operated by an organization, the aircraft of a same type, the aircraft on a same route, the aircraft with a same cabin configuration, or the aircraft within an age range.

6. The aerospace wiring harness inspection system of any one of claims 1 to 5 further comprising:

a computer system configured to:

generate first synthetic wiring harness images with the anomalies using computer-aided design models of wiring harnesses and the anomalies defined by engineering standards;

generate second synthetic wiring harness images with the anomalies using real images of the wiring harnesses with the anomalies;

classify the first synthetic wiring harness images and the second synthetic wiring harness images in which classifying forms labels for the first synthetic wiring harness images and the second synthetic wiring harness images;

add the first synthetic wiring harness images and the second synthetic wiring harness images with the labels to a training dataset; and

train the machine learning model using the training dataset.

7. The aerospace wiring harness inspection system of any one of claims 1 to 6 further comprising:

a computer system configured to:

create synthetic wiring harness images using a second machine learning model trained to generate the synthetic wiring harness images from wiring harness images in training dataset;

determine whether the synthetic wiring harness images have the anomalies;

add labels to the synthetic wiring harness images to indicate whether the anomalies are present, wherein the synthetic wiring harness images with the anomalies are synthetic wiring anomaly images;

store the synthetic wiring harness images with the labels to create a synthetic training dataset; and

train the machine learning model using the synthetic training dataset.

8. The aerospace wiring harness inspection system of claim 7, wherein the second machine learning model is a generative artificial intelligence model trained in a generative adversarial network to create the synthetic wiring harness images using wiring harness images.

9. The aerospace wiring harness inspection system of any one of claims 1 to 8 further comprising:

a teacher machine learning model that has been trained to detect the anomalies in the images of wiring harnesses; and

a computer system configured to:

train a student machine learning model using the teacher machine learning model in which the student machine learning model is the machine learning model and is smaller in size than the teacher machine learning model.

10. The aerospace wiring harness inspection system of any one of claims 1 to 9, wherein the mobile personal computing device is selected from a group comprising an extension rod, a handheld scanner, a smart phone, a mobile phone, a tablet, smart glasses, augmented reality goggles, a laptop computer, and a smart watch.

11. The aerospace wiring harness inspection system of any one of claims 1 to 10, wherein the aerospace vehicle is selected from a group comprising an aircraft, a

commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a spacecraft, a jet aircraft, and a space shuttle.

12. A platform wiring inspection system comprising:

a mobile personal computing device;

a camera system connected to the mobile personal computing device;

a machine learning model running in the mobile personal computing device, wherein the machine learning model is trained to detect anomalies in images of wiring harnesses for a platform; and

an inspection manager configured to:

control the camera system to generate a set of images of a wiring harness;

send the set of images of the wiring harness to the machine learning model; and

receive a result from the machine learning model indicating whether an anomaly is present in the wiring harness.

13. The platform wiring inspection system of claim 12, wherein the platform is selected from a group comprising a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, an aircraft, a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a

submarine, an automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, and a building.

14. A method for inspecting a wiring harness in an aerospace vehicle, the method comprising:

controlling, by a computer system, a camera system to generate a set of images of the wiring harness in the aerospace vehicle, wherein the camera system is connected to a mobile personal computing device;

sending, by the computer system, the set of images of the wiring harness to a machine learning model, wherein the machine learning model is trained to detect anomalies in a set of images of the wiring harness in the aerospace vehicle; and

receiving, by the computer system, a result from the machine learning model indicating whether an anomaly is present in the wiring harness in the aerospace vehicle.

15. The method of claim 14 further comprising:

storing, by the computer system, images captured by a set of mobile personal computing devices in which storing the images captured from a set of mobile personal computing devices forms stored images;

storing, by the computer system, classifications of the anomalies identified in the images by the set of mobile personal computing devices in association with the stored images;

selecting, by the computer system, images from the stored images in which selecting the images forms selected images;

labeling, by the computer system, the selected images with labels based on the classifications of the anomalies for the selected images; and

performing, by the computer system, additional training of the machine learning model using the selected images with the labels.

16. The method of claim 15, wherein selecting the images comprises:

selecting, by the computer system, images having the anomalies identified in the aircraft fleet in which selecting the images forms selected images, wherein the additional training of the machine learning model results in the machine learning model having increased accuracy in detecting the anomalies in wiring harnesses for the aircraft fleet.

17. The method of claim 16, wherein the aircraft fleet is selected from a group comprising all aircraft operated by the organization, the aircraft of a same type, the aircraft on a same route, the aircraft with a same cabin configuration, or the aircraft within an age range.

18. The method of any one of claims 14 to 17 further comprising:

generating, by the computer system, first synthetic wiring harness images with the anomalies using computer-aided design models of wiring harnesses and the anomalies defined by engineering standards;

generating, by the computer system, second synthetic wiring harness images with the anomalies using real images of the wiring harnesses with the anomalies;

classifying, by the computer system, the first synthetic wiring harness images and the second synthetic wiring harness images in which classifying forms labels for the first synthetic wiring harness images and the second synthetic wiring harness images; and

adding, by the computer system, the first synthetic wiring harness images and the second synthetic wiring harness images with the labels to a training dataset.

19. The method of any one of claims 14 to 18 further comprising:

creating, by the computer system, synthetic wiring harness images using a second machine learning model trained to generate the synthetic wiring harness images from wiring harness images in a training dataset;

determining, by the computer system, whether the synthetic wiring harness images have the anomalies;

adding, by the computer system, labels to the synthetic wiring harness images to indicate whether the anomalies are present, wherein the synthetic wiring harness images with the anomalies are synthetic wiring anomaly images; and

storing, by the computer system, the synthetic wiring harness images with the labels to create a synthetic training dataset.

20. The method of any one of claims 14 to 19 further comprising:

training a student machine learning model using a teacher machine learning model in which the student machine learning model is the machine learning model and is smaller in size than the teacher machine learning model, wherein the teacher machine learning model has been trained to detect the anomalies in the images of wiring harnesses.

21. The method of any one of claims 14 to 20 further comprising:

identifying, by the computer system, a remedial action in response to the result indicating a presence of the anomaly in the wiring harness; and

performing the remedial action on the wiring harness.