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Inventor(s)	Chalkley; Andrew

Autonomous Technician System For Component Handling and Installation

Abstract

Autonomous technician system for component handling and installation is described. In one or more implementations, an autonomous technician comprises one or more robots to perform operations including component condition verification, component transport, and component installation. The one or more robots verify compatibility of the component with a different apparatus, where the component is listed by a seller in an item listing and is purchased by a buyer of the apparatus to which the component is installed by the one or more robots. In variations, the one or more robots transport the component from the seller to a location of the apparatus of the buyer. The one or more robots further utilize various installation protocols based on the condition of the component and a condition of the apparatus.

Inventors: **Chalkley; Andrew (Milwaukie, OR)**

Applicant: **eBay Inc.** (San Jose, CA)

Family ID: **1000007711089**

Assignee: **eBay Inc. (San Jose, CA)**

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Background/Summary

BACKGROUND

[0001] Electronic commerce platforms, also known as e-commerce platforms, support transactions between buyers and sellers of goods and services via item listings. Goods offered by sellers sometimes include components for vehicles, appliances, and other devices. Such platforms support searches by buyers for specific device components, such as those used for repair, augmentation, or replacement of other devices.

[0002] It is often the responsibility of a buyer to ensure that a component purchased via an item listing is suitable for the buyer's intended use of the component. As component compatibility knowledge can vary widely from buyer to buyer, and some buyers prefer to complete transactions with little to no knowledge of whether a component is compatible with their device, situations can occur in which the purchased component is incompatible with the device. Such situations result in buyer and seller frustration. Further, such situations can increase a return rate of purchased items across the platform, which increases a load on the platform to facilitate the item returns, re-list the returned items, and so forth.

SUMMARY

[0003] Techniques for controlling at least one autonomous technician for component handling and installation are described. In one or more implementations, a system for an autonomous technician comprises at least one robot configured to verify a component at a first location, e.g., a location associated with a seller of the component or associated with an e-commerce platform. In particular, the component is verified for an apparatus that is located at a second location, e.g., a location associated with a buyer of the component. The at least one robot verifies compatibility of the component with the apparatus. In one or more implementations, the at least one robot further transports the component to the second location and installs the component in the apparatus.

[0004] This Summary introduces a selection of concepts in a simplified form that are further described below in the Detailed Description. As such, this Summary is not intended to identify essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The detailed description is described with reference to the accompanying figures. Entities represented in the figures are indicative of one or more entities and thus reference is made interchangeably to single or plural forms of the entities in the discussion.

[0006] FIG. **1** is an illustration of an environment in an example implementation that is operable to employ at least one autonomous technician deployable by a service provider system as described herein.

[0007] FIG. **2** depicts an example implementation showing generation of a listing for a component via a service provider system.

[0008] FIG. **3** depicts an example implementation showing a transaction involving a listing for a component from a service provider system and an associated request for assistance from an autonomous technician.

[0009] FIG. **4** depicts an autonomous technician, showing sensors, I/O devices, locomotion framework, and other features of the autonomous technician.

[0010] FIG. **5** depicts an example implementation showing component verification performed by an autonomous technician.

[0011] FIG. **6** depicts an example implementation showing route generation performed by an autonomous technician.
[0012] FIG. **7** depicts an example route generated by an autonomous technician, with the autonomous technician indicated at a first stage of the route.
[0013] FIG. **8** depicts the example route with the autonomous technician indicated at a second stage of the route.
[0014] FIG. **9** depicts the example route of with the autonomous technician indicated at a third stage of the route.
[0015] FIG. **10** depicts an autonomous technician, showing an installation tool framework and component support framework of the autonomous technician.
[0016] FIG. **11** depicts a perspective view of an example dynamic toolhead included by an autonomous technician, with the dynamic toolhead in a retracted condition.
[0017] FIG. **12** depicts another perspective view of the dynamic toolhead with a first portion of the dynamic toolhead extended.
[0018] FIG. **13** depicts another perspective view of the dynamic toolhead with a second portion of the dynamic toolhead extended.
[0019] FIG. **14** depicts another perspective view of the dynamic toolhead with a third portion of the dynamic toolhead extended.
[0020] FIG. **15** depicts an example implementation showing apparatus verification performed by an autonomous technician.
[0021] FIG. **16** depicts an example implementation showing input to an installation control module of an autonomous technician.
[0022] FIG. **17** shows a flow diagram depicting a procedure in an example implementation which includes verifying a component for an apparatus.
[0023] FIG. **18** shows a flow diagram depicting a procedure in an example implementation which includes transporting a component for an apparatus from a seller location to a buyer location.
[0024] FIG. **19** shows a flow diagram depicting a procedure in an example implementation which includes installing a component for an apparatus.
[0025] FIG. **20** depicts a procedure in an example implementation of an autonomous technician system for component handling and installation.
[0026] FIG. **21** illustrates an example system that includes an example computing device that is representative of one or more computing systems and/or devices for implementing the various techniques described herein.

DETAILED DESCRIPTION

Overview

[0027] Service provider systems support e-commerce platforms and provide access to item listings. Buyers navigate the item listings via an application such as a web browser or web-based application (e.g., a “mobile app”) to locate items for purchase. Item listings managed by a service provider system and made available for browsing via the e-commerce platform are often directed toward different types of items or categories of items. For example, some item listings are directed toward consumer electronics, while other item listings are directed toward automotive accessories.
[0028] Such platforms support item listings for components that are configured to be installed to other devices, such as memory and storage components for computing devices, and/or filters, radios, cameras, and engine parts for vehicles. Indeed, e-commerce platforms may publish item listings for any of a variety of items that are “components” intended to be installed in relation to or otherwise combined with another device, system, or apparatus. Buyers navigate the item listings and complete transactions via the item listings to order such components. In one example scenario, for instance, a buyer possesses a vehicle of a particular make and model, and the buyer desires to order a replacement side mirror for the vehicle. The buyer navigates through item listings for various vehicle side mirrors and identifies an item listing describing a side mirror that the buyer

believes will be compatible with the make and model of their vehicle. The buyer then completes a transaction via the item listing to purchase the side mirror and receives the side mirror via a delivery service or local pick-up.

[0029] Often, buyers are expected to determine via their own knowledge or expertise whether a given component described by an item listing is compatible with a device or apparatus owned by the buyer, such as a vehicle. However, sometimes buyers do not possess sufficient knowledge to accurately assess whether a listed component is compatible. Buyers that purchase components with an expectation that the components are compatible with their devices can become frustrated once the components are delivered, and the buyers discover that the components cannot be installed due to unexpected compatibility issues.

[0030] Some conventional approaches toward reducing occurrences of unexpected compatibility issues include implementation of search filters that utilize device information input by buyers. For example, a buyer searching for a component for a particular device inputs information describing the device via an interface. The platform searches a catalog of different devices based on the information provided by the buyer. The platform identifies which device entry within the catalog has attributes that match the description of the device input by the buyer. The identified device entry is associated with a particular group of compatible components, and listings for the components identified as compatible with the device are provided to the buyer by the platform as search results. In one example scenario, a buyer inputs information describing the make and model of their vehicle, and the platform returns item listings for components compatible with the particular vehicle.

[0031] However, such approaches can be subject to error. As one example, such approaches do not consider oversights or misrepresentations in the descriptions of the components in the item listings. In conditions in which the description of a component in an item listing is not accurate in view of the actual component delivered to the buyer, unexpected compatibility issues can occur. Further, such approaches rely on information provided by the buyer to accurately identify the apparatus (e.g., the device) of the buyer. In some situations, the buyer does not possess such information or provides inaccurate information.

[0032] Further, even if a buyer completes a transaction for a component that is compatible with their apparatus, the buyer may not have sufficient knowledge to perform installation of the component. Buyers may become frustrated if installation is more complex than anticipated and/or sufficient instructions are not provided. Thus, it is desirable to reduce occurrences of component incompatibility and increase a success of component installation.

[0033] Accordingly, techniques for component condition verification and component installation are described herein that address these technical challenges. In one or more implementations, a robot or plurality of robots forms an autonomous technician configured to perform operations including verifying whether a component purchased via an item listing matches a description of the component within the item listing. The autonomous technician detects the condition of the component via one or more sensors and determines an identifier of the component. The autonomous technician compares the identifier to known identifiers to determine whether the component is compatible with an apparatus of the buyer. In one or more implementations, after compatibility is determined, the autonomous technician is further configured to transport the purchased component to a location of the buyer and/or perform installation of the component to the apparatus of the buyer. To do so, the autonomous technician employs a locomotion framework to transport the purchased component to the location of the buyer, and an installation tool framework to install the component to the apparatus of the buyer.

[0034] In one or more implementations, the autonomous technician is further configured to communicate electronically with the service provider system supporting the e-commerce platform. For example, the autonomous technician communicates with the service provider system via a wired or wireless connection to receive instructions for deployment, to receive data from databases of the service provider system, to receive component transaction information, and so forth.

[0035] In accordance with the described techniques, for instance, following completion of a transaction using an item listing involving a seller of a component and a buyer of the component, the autonomous technician receives a communication from the service provider system. Examples of the communication include, but are not limited to, communications to deploy the autonomous technician to perform operations including component verification, component transport, and component installation, to name just a few. The autonomous technician receives the component from the seller, e.g., by picking up the component at the location of the seller. In one or more implementations, the autonomous technician further transports the component to the location of the buyer and/or installs the component to an apparatus at the location of the buyer.

[0036] In some implementations, the autonomous technician includes a single robot configured to perform all the operations including the verification of the condition of the component, the transport of the component to location of the buyer, and the installation of the component to the apparatus of the buyer. In other implementations, the autonomous technician includes multiple robots, such that each robot is configured to perform different operations. In one example, a first robot performs operations associated with verification of the condition of the component. A second robot receives the component from the first robot and transports the component to the location of buyer. A third robot receives the component delivered to the location of the buyer by the second robot and installs the component to the apparatus of the buyer. In another example, the autonomous technician includes two robots, with the first robot configured to perform the verification of the condition of the component and with the second robot configured to install the component to the apparatus of the buyer. In this example, the first robot and/or the second robot transports the component to the location of the buyer following the verification of the condition of the component. It is to be appreciated that the autonomous technician may include any number of robots at each stage of the process, e.g., one or more robots to perform verification, one or more robots to transport the item, and/or one or more robots to install the item. Additionally, a given robot may be configured to perform one or more of the steps, e.g., verification, transportation, and installation, without departing from the spirit of the described techniques.

[0037] In one or more implementations, a robot of the autonomous technician that performs installation of the component to the apparatus includes a dynamic toolhead that is adjustable based on installation operations to be performed by the robot. The dynamic toolhead includes various tools that are stowed or extended based on the installation operations to be performed. For example, during installation of a first fastener of the component to the apparatus, the dynamic toolhead extends a first tool to rotate the first fastener and stows other tools not used to rotate the first fastener. During installation of a different, second fastener, the dynamic toolhead extends a second tool to engage with the second fastener and optionally stows the first tool. Operation of the dynamic toolhead is controlled via one or more machine learning models in some implementations, resulting in increased adaptability of the robot for a variety of different component installation operations. By configuring the autonomous technician in this way, the autonomous technician performs operations such as verification of component condition and installation of the component to the apparatus, thereby supplementing services provided by the e-commerce platform to increase buyer confidence and reduce item return rates.

[0038] In some aspects, the techniques described herein relate to a system of one or more robots that implement an autonomous technician, the system including: the autonomous technician configured to perform operations including: verifying a component at a first location for an apparatus that is located at a second location, including verifying compatibility of the component with the apparatus; transporting the component to the second location; and installing the component in the apparatus.

[0039] In some aspects, the techniques described herein relate to a system, wherein the autonomous technician includes one or more sensors, and verifying compatibility of the component with the apparatus includes: assessing the component at the first location using the one or more sensors; determining an identifier of the component based on an output of the one or more sensors during the assessing; and matching the identifier to the apparatus.

[0040] In some aspects, the techniques described herein relate to a system, wherein the autonomous technician includes a dynamic toolhead, and installing the component in the apparatus with the autonomous technician includes: detecting a shape of a fastener to be rotated during the installing; and adjusting the dynamic toolhead based on the detected shape of the fastener.

[0041] In some aspects, the techniques described herein relate to a system, wherein the autonomous technician includes: one or more sensors; a locomotion framework; and a reasoning module configured to receive feedback from the one or more sensors and issue commands to the locomotion framework based on the received feedback.

[0042] In some aspects, the techniques described herein relate to a system, wherein the autonomous technician includes a component recognition machine learning model stored in memory, the component recognition machine learning model trained on data including a plurality of component identifiers, and the determining of the identifier of the component is performed using the component recognition machine learning model.

[0043] In some aspects, the techniques described herein relate to a system, wherein the autonomous technician includes an installation procedure machine learning model stored in memory, the installation procedure machine learning model trained on data including a plurality of installation instructions, and installing the component in the apparatus is performed using the installation procedure machine learning model.

[0044] In some aspects, the techniques described herein relate to a system, wherein the autonomous technician includes a component recognition machine learning model and an installation procedure machine learning model, the component recognition machine learning model trained on data including a plurality of component identifiers and the installation procedure machine learning model trained on data including a plurality of installation instructions, and an output of the component recognition machine learning model is an input of the installation procedure machine learning model.

[0045] In some aspects, the techniques described herein relate to a system, wherein the autonomous technician includes a location and routing module, and transporting the component to the second location includes: receiving transaction data associated with the component, the transaction data including location data describing the second location; generating a route to the second location via the location and routing module based on the location data; and transporting the component along the route to the second location.

[0046] In some aspects, the techniques described herein relate to a system, wherein the autonomous technician includes a first robot configured to perform the verifying of the component at the first location for the apparatus that is located at the second location, and a second robot configured to perform the installing of the component in the apparatus.

[0047] In some aspects, the techniques described herein relate to a system, wherein the autonomous technician includes a network communication module configured to retrieve component installation data via wired or wireless communications responsive to determining an identifier of the component using one or more sensors.

[0048] In some aspects, the techniques described herein relate to a system, wherein the network communication module retrieves the component installation data from a service provider system including a listing of the component.

[0049] In some aspects, the techniques described herein relate to a system, wherein the first location is associated with a seller of the component and the second location is associated with a buyer of the component.

[0050] In some aspects, the techniques described herein relate to a method implemented by one or more robots of an autonomous technician, the method including: verifying, by the autonomous technician, a component at a first location for an apparatus that is located at a second location; transporting, by the autonomous technician, the component to the second location; and installing, by the autonomous technician, the component in the apparatus.

[0051] In some aspects, the techniques described herein relate to a method, wherein verifying the component at the first location for the apparatus that is located at the second location includes: assessing the component, by the autonomous technician, using one or more sensors of the autonomous technician; determining, by the autonomous technician, an identifier of the component based on an output of the one or more sensors during the assessing; and matching, by the autonomous technician, the identifier to the apparatus.

[0052] In some aspects, the techniques described herein relate to a method, wherein transporting the component to the second location includes: receiving, by the autonomous technician, location data describing the second location; generating, by the autonomous technician, a route to the second location based on the location data; and transporting, by the autonomous technician, the component along the route to the second location.

[0053] In some aspects, the techniques described herein relate to a method, wherein verifying the component at the first location for the apparatus that is located at the second location is performed by the autonomous technician using a first machine learning model of the autonomous technician, and installing the component in the apparatus is performed by the autonomous technician using a second machine learning model of the autonomous technician.

[0054] In some aspects, the techniques described herein relate to a method, wherein the first machine learning model is trained on data describing a plurality of known component identifiers, and the second machine learning model is trained on data describing a plurality of installation protocols.

[0055] In some aspects, the techniques described herein relate to a method, further including: verifying, by the autonomous technician, a condition of the apparatus that is located at the second location by: acquiring, by the autonomous technician, image data describing the apparatus using one or more sensors of the autonomous technician; detecting, by the autonomous technician, a condition of the apparatus based on the image data; and determining, by the autonomous technician, whether the detected condition of the apparatus matches a described condition of the apparatus using a machine learning model.

[0056] In some aspects, the techniques described herein relate to one or more computer-readable storage media storing executable instructions which, responsive to execution by an autonomous technician implemented by one or more robots, cause the autonomous technician to perform operations including: verifying a component at a first location for an apparatus that is located at a second location, including verifying compatibility of the component with the apparatus; transporting the component to the second location; and installing the component in the apparatus.

[0057] In some aspects, the techniques described herein relate to one or more computer-readable storage media, the operations further including: inputting data describing the component to a first machine learning model for the verifying of the component; generating a route from the first location to the second location to be travelled by the autonomous technician for the transporting of the component to the second location; inputting data describing one or more installation protocols to a second machine learning model for the installing of the component in the apparatus; and verifying a condition of the apparatus that is located at the second location by inputting data describing the apparatus to a third machine learning model.

[0058] In the following discussion, an exemplary environment is first described that may employ the techniques described herein. Examples of implementation details and procedures are then described which may be performed in the exemplary environment as well as other environments. Performance of the exemplary procedures is not limited to the exemplary environment and the exemplary environment is not limited to performance of the exemplary procedures.

Example of an Environment

[0059] FIG. **1** is an illustration of an environment **100** in an example implementation that is operable to employ techniques for an autonomous technician as described herein. The illustrated environment **100** includes a service provider system **102**, which is configurable in a variety of ways.

[0060] In variations, the service provider system **102** is or includes a computing device or multiple computing devices communicatively coupled to each other. The service provider system **102** supports operation of the modules and other systems described herein to implement a platform **122**. The platform **122** is implemented as an electronic commerce (e-commerce) website or other online marketplace accessible to end users. End users access the platform **122** via electronic devices external to the service provider system **102**. In this example, those devices include buyer computing device **112** and seller computing device **108**. The external electronic devices are configurable as personal computers, smartphones, and so forth. The platform **122** is accessible to end-users over a network **104**. The network **104** in some instances is the Internet.

[0061] In one or more implementations, the service provider system **102** includes one or more of electronic storage media, transitory memory and non-transitory memory, one or more electronic processors, and other components configured to facilitate operation of the platform **122**. The service provider system **102** in some instances includes multiple servers, databases, and/or other electronic devices to support storage of data, such as item listings, transaction data, buyer and seller profile information, and other data associated with operation of the service provider system **102** and/or content provided by the service provider system **102** to end users. In such configurations, the multiple servers and/or other electronic devices are utilized to perform operations "over the cloud" as described in relation to FIG. **21**.

[0062] The service provider system **102** is also configured to communicate electronically with databases **106**, such as for storage and retrieval of data associated with item listings. In one or more implementations, the databases **106** include non-transitory storage media configured to store data used in the listings of items. The data is retrieved by the service provider system **102** and is then provided to the external devices for browsing of the item listings through platform **122**. Examples of item listing data include but are not limited to a digital image of the associated item, a video of the associated item, a price of the item, a written description of the item, a condition of the item, an ownership history of the item, and an authenticity designation of the item, to name just a few. The item listing data therefore represents a grouping of data. The data is associated with the item and is used to electronically publish the listing of the item.

[0063] In one or more implementations, the buyer computing device **112** utilizes an application such as a website browser to navigate to the platform **122**. Alternatively or in addition, the buyer computing device **112** utilizes a separate application, such as a web-based application (e.g., a "mobile app") installed on the buyer computing device **112**, to access user interfaces of the platform **122**. The buyer computing device **112** further accesses the functionality and/or services of the platform **122** by extension of the user interfaces of the platform **122**. In accordance with the described techniques, the buyer computing device **112** communicates a request to the service provider system **102** to view one or more item listings. The service provider system **102** then retrieves data associated with the item listings from the databases **106**. The service provider system **102** further provides access to the item listings to the buyer computing device **112** via the platform **122**.

[0064] Item listings are generated through interaction of seller computing devices with the service provider system **102**. For example, the seller computing device **108** communicates information describing a component **110** to be offered for sale via an item listing to the service provider system **102** through use of the platform **122**. The information describing the component **110** is stored within the databases **106** and is used to populate the item listing associated with the component **110** on the platform **122**. The item listing is also stored within the databases **106** and is implemented as a webpage or other user interface (e.g., an item page within a web-based application) of the platform **122**. The buyer computing device **112** is able to view the item listing through interaction with the platform **122** as described above.

[0065] In accordance with the described techniques, the service provider system **102** is also in electronic communication with one or more robots, such as robot **116**. The one or more robots are referred to collectively herein as an autonomous technician **120**. The autonomous technician **120** is implemented to perform operations such as component condition verification, component transport, and component installation, as above and below. In at least some implementations, the platform **122** deploys the autonomous technician **120** responsive to completion of a transaction through the platform **122**.

[0066] As one example, consider a scenario in which a buyer, utilizing the buyer computing device **112**, completes a transaction through the platform **122** to purchase the component **110** described by an item listing published by the platform **122**. In this example, the component **110** is an accessory or replacement part for an apparatus **114** of the buyer. The service provider system **102** communicates a prompt to the buyer computing device **112** to confirm whether installation assistance for the component **110** is desired. In other words, the service provider system **102** prompts the buyer to select via a user interface whether or not to involve the autonomous technician **120**, such as by deploying the autonomous technician **120** to perform one or more of verification, transportation, and/or installation of the component **110**. In this scenario, the buyer computing device **112** responds by confirming that installation assistance is desired, e.g., by providing a selection via the user interface to deploy the autonomous technician **120**. In this example, the confirmation indicates that the component **110** will be installed to the apparatus **114** of the buyer. Responsive to the confirmation, the service provider system **102** communicates deployment instructions to the autonomous technician **120**. By way of example, the deployment instructions include, for instance, commands to perform one or more operations such as verifying a condition of the component **110**, transporting the component to the location of the buyer, and installing the component **110** to the apparatus **114** of the buyer. In the continuing example, based on the instructions, the autonomous technician **120** is deployed and it verifies the component (e.g., at a location of the seller), transports the component to the apparatus **114**, and installs the component **110** to the apparatus **114** to form the assembly **118**.

[0067] Performing component verification via the autonomous technician **120** provides the technical effect of reducing occurrences of unexpected component incompatibility with devices of component buyers. Additionally, the operations performed by the autonomous technician **120** result in various other technical effects.

[0068] As one example, the autonomous technician **120** verifies the condition of the component **110**. The autonomous technician detects the condition of the component **110** and compares the detected condition to the condition described by the item listing. This reduces a likelihood of degradation of the component **110** or other unexpected aspects of the component **110** interfering with installation of the component **110** to the apparatus **114**. Additionally, the verification of the condition of the component **110** by the autonomous technician **120** can reduce or eliminate back-and-forth communications through the platform **122** that result from miscommunication of the condition of the component **110** in the item listing, which reduces a communication and/or processing load on the platform **122**. Similarly, the verification reduces occurrences of return shipping communications through the platform **122**, further reducing the communication and/or processing load on the platform **122**.

[0069] The autonomous technician **120** further verifies the compatibility of the component **110** with the apparatus **114** by referencing one or more compatibility libraries after detecting the actual condition of the component **110**. This provides an additional layer of assurance of the compatibility of the component **110** with the apparatus **114** by identifying potential issues not described in the item listing that can interfere with installation of the component **110**.

[0070] In addition to the verification of the condition of the component **110**, in one or more implementations, the autonomous technician **120** verifies the actual condition of the apparatus **114** prior to installation of the component **110** to the apparatus **114**. Verifying the actual condition of the apparatus **114** includes detecting features of the apparatus **114** by assessing and/or measuring the apparatus **114** itself. As a result, the autonomous technician **120** can identify potential issues that may occur with installation of the component **110** to the apparatus **114** due to one or more conditions of the apparatus **114**, e.g., previous modifications or installations made to the apparatus **114**.

[0071] In one or more implementations, the autonomous technician **120** is configured to adapt to such conditions by updating the installation protocol for the component **110** and installing the component **110** to the apparatus having the detected one or more conditions using the updated protocol.

[0072] In situations in which information describing the apparatus **114** is stored to a profile of the buyer on the platform **122**, the autonomous technician **120** can update the stored information based on the actual condition of the apparatus **114**. This in turn increases an accuracy of the information describing the apparatus **114**, which increases an ease and precision of further installations to the apparatus **114**. Further, if the autonomous technician **120** detects an inconsistency in the information stored in the compatibility libraries based on the detected actual condition of the apparatus **114**, the autonomous technician **120** can communicate with the databases **106** to update the compatibility libraries and/or installation protocols accordingly. This increases an accuracy of the compatibility information and effectiveness of installation protocols to increase success for future component installation operations.

[0073] By transporting the component **110** to the location of the apparatus **114**, the autonomous technician **120** reduces an amount of time and/or cost associated with shipping the component **110**. Further, because the location of the autonomous technician **120** is tracked by the service provider system **102**, a precision of tracking the location of the component **110** as the component **110** travels with the robot **116** is increased relative to conventional delivery approaches such as a postal service. In one or more implementations, a form factor and/or structure of the robot **116** can reduce a likelihood of degradation of the component **110** while the component **110** is transported to the location of the apparatus **114** in comparison with conventional delivery approaches. For instance, the autonomous technician **120** can include multiple different robots. Based on the attributes of the component **110**, a particular robot having a form factor and structure can be selected for deployment to increase support of the component **110** during transportation and reduce a likelihood of degradation of the component **110**. In some instances, a weight capacity of the deployed robot is higher than a weight capacity associated with delivery of the component **110** via a postal service. Thus, the autonomous technician **120** supports transportation of components that would otherwise encounter difficulties with conventional delivery approaches.

[0074] Installing the component **110** to the apparatus **114** using the autonomous technician **120** increases a likelihood of installing the component **110** in accordance with installation instructions of the component **110** in comparison to other approaches, such as installation by humans. The autonomous technician **120** may also be more precise than a human installer when installing the component **110**. Installing the component **110** in accordance with the installation instructions of the component **110** and with greater precision increases a reliability of the installation and/or durability of the resulting assembly **118**. Such installation may also reduce a likelihood of unintended surface contact or occurrence of other adverse conditions that may result in degradation of portions of the apparatus **114** and/or component **110**.

[0075] Further, the autonomous technician **120** may also support advanced and/or complicated installation protocols that would be difficult or impractical for humans to perform. For example, a shape and/or structure of the robot **116** can facilitate installation of the component **110** to areas of the apparatus **114** that are difficult or impossible for humans to access. The robot **116** further may employ devices with lifting capabilities to lift portions of the apparatus **114** and/or the component

110 that would otherwise be difficult or impossible for a human to lift. Additionally, following installation of the component **110** to the apparatus **114**, the autonomous technician **120** is operable to verify the installed condition of the component **110** in the assembly **118** and/or test operation of the assembly **118** to confirm the quality of the installation.

[0076] In general, functionality, features, and concepts described in relation to the examples above and below are employed in the context of the example procedures described in this section. Further, functionality, features, and concepts described in relation to different figures and examples in this document are interchangeable among one another and are not limited to implementation in the context of a particular figure or procedure. Moreover, blocks associated with different representative procedures and corresponding figures herein are applicable together and/or combinable in different ways. Thus, individual functionality, features, and concepts described in relation to different example environments, devices, components, figures, and procedures herein are usable in any suitable combinations and are not limited to the particular combinations represented by the enumerated examples in this description.

Autonomous Technician Component Handling and Installation

[0077] The following discussion describes techniques for an autonomous technician that are implementable utilizing the described systems and devices. Aspects of the procedures are implemented in hardware, firmware, software, or a combination thereof. The procedures are shown as sets of blocks that specify operations performable by hardware and are not necessarily limited to the orders shown for performing the operations by the respective blocks. Blocks of the procedures, for instance, specify operations programmable by hardware (e.g., processor, microprocessor, controller, firmware) as instructions thereby creating a special purpose machine for carrying out an algorithm as illustrated by the flow diagram. As a result, the instructions are storable on a computer-readable storage medium that causes the hardware to perform the algorithm.

[0078] FIGS. **17-19** show flow diagrams depicting algorithms as step-by-step procedures. In particular, FIG. **17** depicts procedure **1700** for verifying a condition of a component via an autonomous technician, FIG. **18** depicts procedure **1800** for transporting a component to a location of a buyer via an autonomous technician, and FIG. **19** depicts procedure **1900** for installing a component to an apparatus of a buyer via an autonomous technician. In portions of the following discussion, reference will be made to FIGS. **1-16** in parallel with the procedure **1700** of FIG. **17**, the procedure **1800** of FIG. **18**, and the procedure **1900** of FIG. **19**. In some implementations, the procedures depicted by FIGS. **17-19** are performed via a single robot of an autonomous technician, e.g., the robot **116**, while in others the procedures are performed by one or more robots.

[0079] Referring to FIG. **2**, an example implementation of service provider system **102** is shown, depicting operations for generating a component listing **202**. In this example, a seller inputs information describing an item to be listed via the platform **122** implemented by the service provider system **102**. The item is a component for a device or apparatus, such as a part for installation to a vehicle. The seller computing device **108** communicates the information input by the seller to the service provider system **102**, which is represented as component listing data **200**. Responsive to receiving the component listing data **200**, the service provider system **102** generates and publishes the component listing **202**. The component listing **202** includes the information about the component (e.g., the item) provided by the seller based on received inputs or otherwise associated with the component listing **202**, e.g., generated automatically by one or more machine learning models. By way of example and not limitation, the component listing data **200** includes one or more of digital images of the component, video of the component, text descriptions of the component, selected categories of the component, selected or described condition of the component, description of wear of the component, description of compatibility of the component, make and/or model of the component, price of the component, description of similar components, ownership history, and so on. The component listing **202** is stored using one or more databases of the service provider system **102**, such as the databases **106**.

[0080] Referring to FIG. **3**, an example implementation depicting operations for generating a robot assistance request **308** responsive to a transaction involving an item listing is shown. In the example, a buyer utilizes the buyer computing device **112** to communicate information to the service provider system **102** through the platform **122**. The communicated information includes apparatus compatibility data **300** and search criteria **302**.

[0081] The apparatus compatibility data **300** includes information describing the apparatus **114** of the buyer. Such information includes, for example, a make and/or model of the apparatus **114**, a manufacturer of the apparatus **114**, a date of manufacture of the apparatus **114**, one or more images of the apparatus **114** or portions of the apparatus **114**, one or more videos of the apparatus **114** or portions of the apparatus **114**, and so forth. It is to be appreciated that the compatibility data **300** may include a variety of information and/or types of information that describe or otherwise convey aspects about the apparatus **114** which relate to its compatibility without departing from the spirit or scope of the described techniques. The apparatus compatibility data **300** is utilized by the service provider system **102** to filter search results provided to the buyer, as described below.

[0082] The search criteria **302** includes information describing a component sought for purchase for installation to the apparatus **114** of the buyer. For example, the search criteria **302** is a search query that includes one or more of text, voice, images, or video. In one instance, the apparatus **114** is a vehicle, and the search criteria **302** specifies a type of vehicle component, such as a vehicle radio.

[0083] The service provider system **102** receives the apparatus compatibility data **300** and the search criteria **302**. The service provider system **102** then communicates at least one retrieved item listing to the buyer computing device **112** based on the apparatus compatibility data **300** and the search criteria **302**. One such item listing is component listing **202**. The service provider system **102** identifies the component listing **202** from a plurality of item listings using the apparatus compatibility data **300** and the search criteria **302**.

[0084] In at least one implementation, the service provider system **102** determines a first set of item listings from the plurality of item listings based on the apparatus compatibility data **300**. The item listings within the first set of item listings are associated with items that are compatible with the apparatus **114** (for installation to the apparatus **114**) according to information included in the item listings. The service provider system **102** determines whether the items are compatible with the apparatus **114** by comparing the apparatus compatibility data **300** to data within one or more compatibility libraries of the databases **106** and/or to data included in the item listings which may indicate compatibility, e.g., a list of makes and/or models with which the component of the item listing is compatible.

[0085] The service provider system **102** further determines a second set of item listings from the first set of item listings. The second set of item listings is a subset of the first set of item listings and is based on the search criteria **302**, e.g., item listings that further match the search criteria **302**. Thus, the second set of listings includes listings from the first set that additionally conform to the search criteria **302**. As noted above, the search criteria **302** may specify a particular type of item or component, and the search criteria **302** is usable to further filter the set of item listings for components that are determined compatible with the apparatus **114**.

[0086] Consider a scenario in which the apparatus **114** is a vehicle of a particular make and model. In one or more implementations, the first set of item listings includes listings for components that are compatible with the vehicle of the particular make and model. Further in this scenario, the search criteria **302** describes a particular type of item, such as vehicle radios. The first set of listings thus includes listings for components that are compatible with the vehicle, and the second set of listings includes listings for vehicle radios that are compatible with the vehicle.

[0087] Although in this scenario the service provider system **102** determines the first set of item listings from the apparatus compatibility data **300** and determines the second set of item listings from the first set of item listings, in some cases these operations are reversed. For instance, the service provider system **102** may determine a first set of item listings based on the search criteria, and determine the second set of item listings from the first set based on the apparatus compatibility data **300**.

[0088] In order to complete the transaction for the component **110**, the buyer computing device **112** provides input **304** which is received by service provider system **102**. In one or more implementations, the input **304** includes data for executing the transaction for the component **110**, examples of which include electronic communication of payment information, buyer location information, delivery selection information, and so forth. The information associated with the completed transaction is represented as transaction data **306**.

[0089] In at least one implementation, the input **304** includes confirmation that installation assistance for the component **110** is requested, e.g., as robot assistance request **308**. In accordance with the described techniques, the service provider system **102** communicates the transaction data **306** and the robot assistance request **308** to the autonomous technician **120** as part of instructions for deployment of the autonomous technician **120**. As a result, the autonomous technician **120** is deployed to perform at least one of item verification, item transportation, and/or item installation operations as described herein via one or more robots, such as the robot **116**.

[0090] Referring to FIG. **4**, one example implementation of the robot **116** is shown. The robot **116** includes various modules and components which enable the robot **116** to perform one or more operations, such as component condition verification, component transportation, and component installation. It is to be appreciated that a robot configured to perform any one or more or portions of those operations may include more, different, or fewer components than depicted in FIG. **4** without departing from the spirit or scope of the described techniques.

[0091] Alternatively or additionally, the robot **116** is one of two or more robots employed by the autonomous technician **120** to perform any of the various operations described herein. Each of the two or more robots may include various subsets, all, or different components of the configuration depicted in FIG. **4**. As one example, the autonomous technician **120** is configurable to include a first robot and a second robot, where the first robot includes a condition verification module **440** and does not include an installation tool framework **434**, and where the second robot includes the installation tool framework **434** and does not include the condition verification module **440**.

[0092] In this example, the depicted robot **116** includes sensors **400**. The sensors **400** are employed by the robot **116** to sense conditions within an environment of the robot **116** and/or measure parameters associated with an item (e.g., component **110**). The sensors **400** may include, in one or more implementations, at least one of a camera **402**, a microphone **404**, an on-board diagnostics (OBD) interface **406**, a multimeter **408**, a microscope **410**, a scale **412**, a radio frequency (RF) detector **414**, and a spectrometer **416**, to name a few. In some implementations, the robot **116** includes different, fewer, or additional sensors, and/or one or more of the sensors shown in FIG. **4** are omitted.

[0093] In at least one scenario, the robot **116** uses sensors **400** to perform verification of a condition of an item involved in a transaction through an item listing. Performing the condition verification includes electronic communication between the sensors **400** and the condition verification module **440**. The condition verification module **440** receives measurements and/or other data from the sensors **400** and provides commands to control the sensors **400** (and/or architectures of the robot **116**) to acquire those measurements and/or other data. In performing the verification of the item condition, the robot **116** may, for instance, capture digital image data of the item via the camera **402**, the microscope **410**, and/or the spectrometer **416**. The robot **116** may then compare the captured digital image data to other reference digital image data, such as digital images of the item provided by the manufacturer that are maintained in the database **106**. Based on the comparison, the robot **116** determines whether the condition of the item matches (or substantially matches) the condition represented by the reference data. In one or more implementations, this determination may be performed by employing one or more machine learning models to analyze the digital image data acquired via the sensors and compare the data to the reference digital image data.

[0094] In at least one implementation, the determination includes matching one or more identifiers of the item indicated by the reference data to one or more identifiers or identifying features identified in the digital images acquired by the sensors **400**. For instance, the one or more machine learning models are trained to perform image recognition operations such as edge detection, image segmentation, pattern detection, and so forth to identify identifiers or identifying features within the digital images.

[0095] Further, in some implementations, the robot **116** acquires other data from the sensors **400** and compares such other acquired data to other reference data included within databases **106**. For instance, the robot **116** acquires a weight of the item via a scale **412** and compares the weight to an expected weight for the item stored in the reference data. Based on the comparison, the robot **116** determines whether the measured weight is within a tolerance of the reference weight (e.g., less than 5% difference from the reference weight). The reference weight and the measured weight are thus identifiers of the item that are matched by the robot **116**. The item condition verification performed by the robot **116** includes multiple operations in some examples, such as determining that the visual appearance of the item matches the visual appearance represented by the reference data, the measured weight of the item matches the reference weight, and so forth.

[0096] The robot **116** additionally includes input/output devices **418** providing an interface between persons within a proximity of the robot **116** and various control modules and other components of the robot **116**. The robot **116** is shown including a speaker **420** configured to output audio signals, a display screen **422** configured to output information for display, and a keyboard **424** configured to receive input for communication between individuals and the robot **116**. In some implementations, the input/output devices **418** include a different configuration with more, fewer, or different input/output devices **418**.

[0097] In one or more implementations, the input/output devices **418** communicate with a text-to-speech module **442**, such as to convert text data to audio signals and vice-versa. For example, the robot **116** receives text input via the keyboard **424** and outputs audio signals via speaker **420**, including speech based on the textual data. In one or more implementations, microphone **404** is used by the text-to-speech module **442** to receive audio signals, and the text-to-speech module **442** converts the received audio signals to textual data. In one or more implementations, the robot **116** is able to communicate with the buyer through the buyer computing device **112** and/or communicate with the seller through the seller computing device **108**. Those communications may include, for instance, electronic communications transmitted to the buyer computing device **112** and/or the seller computing device **108**, such as by using a short-range wireless transmitter integrated into a network communication module **438**. Alternatively or additionally, the robot **116** communicates electronically with the service provider system **102**, which then communicates electronically with the buyer computing device **112** and/or the seller computing device **108** to provide communications related to operation of the robot **116** to the buyer and/or to the seller.

[0098] In at least one implementation, the robot **116** includes a locomotion framework **426** with components employed to support locomotion of the robot **116**, e.g., travel of the robot **116** from one location to another. The locomotion framework **426** is shown including wheels **428**, a gyroscope **430**, propellers **432**, and a locomotion controller **450**. It is to be appreciated, however, that the locomotion framework **426** can include more, different, or fewer components to support movement of the robot without departing from the spirit or scope of the described techniques.

[0099] By way of example, the wheels **428** are employed by the robot **116** for ground travel, and the propellers **432** are employed by the robot **116** for aerial travel. In some implementations, the robot **116** is configured as an unmanned aerial vehicle (UAV), also referred to as a drone. However, in other implementations, the robot **116** includes wheels **428** or other devices for ground travel and does not include the propellers **432**. The gyroscope **430** supports upright travel of the robot **116** and travel of the robot **116** over diverse ground terrain, such as unpaved land.

[0100] In one or more implementations, the locomotion controller **450** controls operation of the components of the locomotion framework **426** based on signals received at the locomotion controller **450** from the sensors **400**. Such signals may include, for instance, one or more of image data from the camera **402** and audio data from the microphone **404**. The locomotion controller **450** additionally receives signals and data from a location and routing module **444**, such as data describing a geographical location of the robot **116**. In some implementations, the robot **116** is a stationary robot and does not include the locomotion framework **426**.

[0101] The locomotion framework **426** is configured to communicate electronically with the location and routing module **444** for locomotion of the robot **116**. The location and routing module **444** processes location data of the robot **116**, such as data describing a geographical location of the robot **116**. The location data is acquired via the network communication module **438** by the robot **116** via communication with one or more sources of location data, such as global positioning systems, wireless routers, cellular network components, and so forth. The location and routing module **444** identifies the geographical location of the robot **116** and may generate travel routes for the robot **116** based on the location data of the robot as well as based on other entities.

[0102] In one example scenario, the robot **116** receives the transaction data **306**. The location and routing module **444** processes the transaction data **306** and generates at least a portion of a route to a location of the seller with the component **110**. Alternatively or additionally, the location and routing module **444** generates at least a portion of a route to a location of the buyer associated with the apparatus **114**. The location and routing module **444** further communicates electronically with the locomotion framework **426** to support the travel of the robot **116** along the one or more routes.

[0103] The robot **116** is shown including the installation tool framework **434**. The installation tool framework **434** includes components configured to support installation of items to other devices. For instance, the robot **116** employs the installation tool framework **434** to install the component **110** to the apparatus **114**. In one or more implementations, the installation tool framework **434** includes a dynamic toolhead **436**, as described in further detail below. Alternatively or additionally, the robot **116** includes and/or controls one or more of a plurality of different tools. In one or more implementations, the robot **116** controls the dynamic toolhead **436** and/or any of a plurality of different tools to install the component **110** to the apparatus **114**. In one or more scenarios, the robot **116** removes a different component from the apparatus **114** prior to installing the component **110**. For example, the robot **116** employs the installation tool framework **434** to replace a component of the apparatus **114** with the component **110**. Alternatively or additionally, the robot **116** employs the installation tool framework **434** to at least partially remove or disassemble a component of the apparatus **114** and then install the component **110**. In at least one scenario, the robot **116** further employs the installation tool framework **434** to at least partially reinstall or reassemble the at least partially removed or disassembled component after the component **110** is installed.

[0104] To install components, in one or more implementations, the installation tool framework **434** receives instructions and/or commands for installation of the components to one or more other devices or apparatuses. For example, the installation tool framework **434** receives such instructions and/or commands through electronic communication with an installation protocol module **446**. In at least one scenario, for instance, the robot **116** receives the transaction data **306** including information regarding the described condition of the component **110** as provided by the seller. Using the transaction data **306**, the robot **116** communicates with the service provider system **102** and the databases **106** to receive installation protocols related to the installation of the component **110** to the apparatus **114** of the buyer. As described further below, the installation protocol module **446** includes one or more machine learning models that control operations performed using the installation tool framework **434** through the installation protocol module **446**.

[0105] In one or more implementations, the robot **116** further includes a component support framework **448**. In at least one implementation, the robot **116** uses the component support framework **448** in combination with the installation tool framework **434** while performing installation of components to other devices. By way of example, the component support framework **448** includes various grasping implements and other devices that stabilize the apparatus **114** relative to the robot **116** to increase an ease of installation of components to the apparatus. The component support framework **448** is described in greater detail below. In some implementations, the robot **116** controls devices of the component support framework **448** at least in part through electronic communication with the installation protocol module **446**. For instance, the robot **116** uses the installation protocol module **446** to issue commands to the component support framework **448** to control devices of the component support framework **448** for installation of components to other devices.

[0106] In one or more implementations, the robot **116** communicates electronically with the service provider system **102** via the network communication module **438**. The electronic communications via the network communication module **438** include wired or wireless communications. As one example, the robot **116** communicates wirelessly with the service provider system **102** via the network communication module **438** using a cellular telecommunications network. Alternatively or additionally, the robot **116** communicates wirelessly with the service provider system **102** via the network communication module **438** using a wireless (e.g., Wi-Fi) network. Indeed, other communication protocols and/or networks may be used in accordance with the described techniques. In one or more scenarios, the communications are transmitted over the network **104**.

[0107] In some implementations, the robot **116** includes additional components not shown by FIG. **5**. For instance, the robot **116** is configurable to include one or more batteries configured to supply power to the electronic components of the robot **116**. The robot **116** is additionally configurable to include a wired power connection, such as a cabled power supply.

[0108] In the illustrated example, the robot **116** includes a reasoning module **460**. In one or more implementations, the reasoning module **460** coordinates communication between the various components of the robot **116**. For instance, the reasoning module **460** controls electronic communication between the condition verification module **440**, the installation protocol module **446**, and the locomotion controller **450**. The robot **116** thus employs the reasoning module **460** to coordinate and otherwise manage the operations described herein that relate individually to the condition verification module **440**, the installation protocol module **446**, and the locomotion controller **450**. As one scenario, the reasoning module **460** activates the condition verification module **440** to perform component verification. The reasoning module **460** then electronically controls or activates other components of the robot **116** responsive to a result of the component verification.

[0109] The robot **116** as illustrated includes a processing system **452**, one or more computer-readable media **456**, and the input/output devices **418** that are communicatively coupled, one to another. Although not shown, the robot **116** further includes a system bus or other data and command transfer system that couples the various components, one to another. For example, a system bus includes any one or combination of different bus structures, such as a memory bus or memory controller, a peripheral bus, a universal serial bus, and/or a processor or local bus that utilizes any of a variety of bus architectures. A variety of other examples are also contemplated, such as control and data lines.

[0110] The processing system **452** is representative of functionality to perform one or more operations using hardware. Accordingly, the processing system **452** is illustrated as including hardware elements **454** that are configured as processors, functional blocks, and so forth. This includes example implementations in hardware as a system specific integrated circuit or other logic device formed using one or more semiconductors. The hardware elements **454** are not limited by the materials from which they are formed or the processing mechanisms employed therein. For example, processors are comprised of semiconductor(s) and/or transistors (e.g., electronic integrated circuits (ICs)). In such a context, processor-executable instructions are, for example, electronically-executable instructions.

[0111] The computer-readable media **456** is illustrated as including memory/storage **458**. The memory/storage **458** represents memory/storage capacity associated with one or more computer-readable media. In one example, the memory/storage **458** includes volatile media (such as random access memory (RAM)) and/or nonvolatile media (such as read only memory (ROM), Flash memory, optical disks, magnetic disks, and so forth). In another example, the memory/storage **458** includes fixed media (e.g., RAM, ROM, a fixed hard drive, and so on) as well as removable media (e.g., Flash memory, a removable hard drive, an optical disc, and so forth). The computer-readable media **456** is configurable in a variety of other ways as further described below.

[0112] The input/output devices **418** are representative of functionality to allow user input to enter commands and information to the robot **116**, and also allow information to be presented via other components or devices using various input/output devices. Examples of input devices include the keyboard **424**, a cursor control device (e.g., a mouse), an additional microphone or the microphone **404**, a scanner, touch functionality (e.g., capacitive or other sensors that are configured to detect physical touch), an additional camera or the camera **402** (e.g., which employs visible and/or non-visible wavelengths such as infrared frequencies to recognize movement as gestures that do not involve touch), and so forth. Examples of output devices include the display screen **422** (e.g., a monitor or projector), the speaker **420**, a printer, a network card, tactile-response device, and so forth. Thus, the robot **116** is configurable in a variety of ways to support user interaction.

[0113] Implementations of the described modules and techniques are storable on or transmitted across some form of computer-readable media. For example, the computer-readable media includes a variety of media that is accessible to the service provider system **102**. By way of example, and not limitation, computer-readable media includes “computer-readable storage media” and “computer-readable signal media.”

[0114] As previously described, the hardware elements **454** and the computer-readable media **456** are representative of modules, programmable device logic and/or fixed device logic implemented in a hardware form that is employable in some implementations to implement at least some aspects of the techniques described herein, such as to perform one or more instructions. Hardware includes components of an integrated circuit or on-chip system, a system-specific integrated circuit (ASIC), a field-programmable gate array (FPGA), a complex programmable logic device (CPLD), and other implementations in silicon or other hardware. In this context, hardware operates as a computing device that performs program tasks defined by instructions and/or logic embodied by the hardware as well as a hardware utilized to store instructions for execution, e.g., the computer-readable storage media described previously.

[0115] Combinations of the foregoing are also employable to implement various techniques described herein. Accordingly, software, hardware, or executable modules are implementable as one or more instructions and/or logic embodied on some form of computer-readable storage media and/or by one or more the hardware elements **454**. For example, the robot **116** is configured to implement particular instructions and/or functions corresponding to the software and/or hardware modules. Accordingly, implementation of a module that is executable by the robot **116** as software is achieved at least partially in hardware, e.g., through use of computer-readable storage media and/or the hardware elements **454** of the processing system **452**. The instructions and/or functions are executable/operable by one or more articles of manufacture (for example, processing systems **452**) to implement techniques, modules, and examples described herein.

[0116] The techniques described herein are supportable by various configurations of the robot **116** and are not limited to the specific examples of the techniques described herein. This functionality is also implementable entirely or partially through use of a distributed system, such as over a “cloud,” similar to the example cloud shown by FIG. **21** and described further below.

[0117] Referring to FIG. **5**, an implementation example depicting operations for component condition verification is shown. In the depicted implementation, the robot **116** is at a location of the seller and the component **110**. For instance, following completion of a transaction involving the component listing **202**, the robot **116** is deployed by the service provider system **102** to perform condition verification of the component **110**. In some scenarios, the robot **116** travels to the location of the seller and the component **110** using the locomotion framework **426**. In other scenarios, the seller or the platform **122** transports or otherwise delivers the component **110** to the location of the robot **116** for verification of the condition of the component **110** by the robot **116**. The robot **116** is deployable from a location such as a warehouse or other hub that serves as a storage location for the robot **116** during conditions in which the robot **116** is not in use.

[0118] The robot **116** receives the transaction data **306** and the component **110**. The robot **116** assesses the component by acquiring data describing the component **110** via the sensors **400** (block **1702** of FIG. **17**). The data describing the component **110** includes, for instance, digital images of the component **110**, a weight measurement of the component **110**, size measurements of the component **110**, and so forth. The data is provided to the condition verification module **440** which performs the component condition verification, e.g., by using a machine learning model **506**. The machine learning model **506** is referred to herein as a component recognition machine learning model. In some implementations, the machine learning model **506** is a deep neural network trained on data describing various types of components. The condition verification module **440** employs the machine learning model **506** to determine identifiers of the component **110**, such as identifier **510**, that match known identifiers stored in the databases **106** (block **1704** of FIG. **17**). The machine learning model **506** is trained on data describing a plurality of component identifiers that the machine learning model **506** leverages to detect identifiers of the component **110** (and other components provided to the robot **116** for condition verification). In one or more implementations, the machine learning model **506** performs operations such as image recognition, image content matching, and similarity analysis, to name a few.

[0119] The condition verification module **440** communicates with the databases **106** via the network communication module **438** to retrieve reference data used in performing operations for component condition verification. The reference data may include data from a universal purchase code (UPC) database **500**, a manufacturer part number (MPN) database **502**, one or more compatibility libraries such as compatibility library **504**, and so forth.

[0120] As noted above, the robot **116** may acquire data describing the component **110** via the sensors **400**, such as digital images of the actual condition of the component **110**. The robot **116** employs machine learning model **506** to determine one or more identifiers of the component **110** that are used to verify the condition of the component **110**. One such identifier **510** includes a visible manufacturer part number, such as a part number stamped into the component **110** or included on a sticker affixed to the component **110**. Additionally and/or alternatively, the visible manufacturer part number may be included on packaging of the component **110** and acquiring the data describing the component **110** via the sensors **400** may include acquiring the visible manufacturer part number from the packaging of the component **110**.

[0121] The condition verification module **440** detects the manufacturer part number and compares the detected manufacturer part number to a plurality of part numbers, such as from the MPN database **502** associated with various components. The condition verification module **440** confirms that the detected manufacturer part number matches a part number included in the MPN database **502** that is associated with a component. The condition verification module **440** further compares the other detected identifiers to reference data from the databases **106** to confirm whether the identifiers match the reference data associated with component identified by the matched part number in the MPN database **502**. Based on the matching of the identifiers, the condition verification module **440** determines that the component **110** is the same brand and/or make as the component identified by the matched part number in the MPN database **502**.

[0122] Other example identifiers include, but are not limited to, a relative arrangement of edges and/or surfaces of the component **110**, a measured size of the component **110**, a texture and/or patterning of the component **110**, a material of the component **110**, a color of the component **110**, a translucency or transparency of the component **110**, a reflectivity of the component **110**, a labeling of the component **110** (e.g., via stamping, stickers, printing, etc.), and a sound produced by the component **110**, among others.

[0123] In one or more implementations, the condition verification module **440** compares the identified component **110** to the description of the component **110** included in the component listing **202**. For instance, the condition verification module **440** processes the data acquired via the sensors **400** using the machine learning model **506** to determine attributes of the component **110**, such as wear, missing features, surface finish and/or texture, weight, and/or density, to name a few. The condition verification module **440** then determines whether the description of the component **110** from the component listing **202** matches the actual condition of the component **110** based on the determined attributes. Other example characteristics of the component **110** that are detectable via the sensors **400** and the condition verification module **440** include connectivity of wireless communication connections of the component **110** through use of the RF detector **414**, continuity of electrical circuits or other portions of the component **110** through use of the multimeter **408**, connectivity of electronic ports of the component **110** through use of the OBD interface **406**, filter degradation of the component **110** through use of a particulate detector (not shown), and so on.

[0124] The condition verification module **440** further determines whether the component **110** is compatible with the apparatus **114** based on the detected identifiers. For instance, data received by the robot **116** from compatibility library **504** indicates various components that are compatible for installation to the apparatus **114** (based on the apparatus compatibility data **300**). The robot **116** identifies the condition of the component **110** based on the identifiers as described above and determines whether the data from the compatibility library **504** indicates that the component **110** is compatible for installation to the apparatus **114**.

[0125] The compatibility of the component **110** with the apparatus **114** may also depend on an actual condition of the apparatus **114**. For instance, although apparatus compatibility data **300** describes the apparatus **114**, the actual condition of apparatus **114** may be different than the condition described by apparatus compatibility data **300**, such as due to modification, erroneous documentation, wear, manufacture errors, and so on. In order to verify the actual condition of the apparatus **114**, the robot **116** may perform additional verification operations in relation to the apparatus **114** as described further below with reference to FIG. **15**.

[0126] The condition verification module **440** compares the detected identifiers of the component **110** to known reference identifiers included in the compatibility library **504**, UPC database **500**, and/or MPN database **502** that are associated with various apparatuses to determine the compatibility of the component **110** with the apparatus **114** (block **1706** shown by FIG. **17**). Consider a scenario in which the apparatus **114** is a vehicle of a particular make and model. Within the compatibility library **504**, the particular make and model of the vehicle is associated with data describing various identifiers, e.g., serial numbers of parts that are compatible with the make and model of the vehicle. The identifiers associated with the particular make and model of the vehicle include, for instance, a particular electronic connection assembly for a vehicle radio, a particular wheel size, a particular air filter housing length, and so forth.

[0127] The condition verification module **440** compares the detected identifiers of the component **110** to the identifiers in the compatibility library **504** associated with the particular make and model of the vehicle to determine matches between the identifiers. In this example scenario, the component **110** is a vehicle air filter. The condition verification module **440** detects a length of the component **110**, e.g., via measurement of the component **110** through sensors **400**, and stores the detected length as an identifier of the component **110**. The condition verification module **440** then compares the detected length of component **110** to an air filter housing length identifier associated with the apparatus **114** in compatibility library **504** to determine whether the component **110** is compatible with the vehicle, e.g., whether the component **110** fits within the air filter housing of the vehicle.

[0128] The condition verification module **440** outputs a component verification result **508**, such as to the service provider system **102** (block **1708** of FIG. **17**). The component verification result **508** indicates whether the actual condition of the component **110** matches the condition as described in the component listing **202**. If the condition matches, the service provider system **102** commands the robot **116** (or another robot of the autonomous technician **120**) to transport the component to the location of the buyer for installation of the component to the apparatus **114** of the buyer.

[0129] However, if the condition does not match, the service provider system **102** performs a different set of operations. In some implementations, if the condition does not match, the service provider system **102** provides a notification or alert to the buyer through the platform **122**, via text message, or via another type of communication to indicate that the condition of the component **110** is different than the condition as described in the component listing **202**. The service provider system **102** prompts the buyer for confirmation to proceed with delivery of the component or to cancel the transaction. In some implementations, the service provider system **102** cancels the transaction and suggests alternate component listings for similar components to the buyer. Other responses are also possible without departing from the described techniques.

[0130] Referring to FIG. **6**, an implementation depicting operations for determining a travel route of the robot **116** of the autonomous technician **120** is shown. The robot **116** includes the location and routing module **444** which receives the transaction data **306** and the component listing data **200** (block **1802** of FIG. **18**). The transaction data **306** includes buyer location data **600** and seller location data **602**. The buyer location data **600** includes data identifying a location (e.g., physical address) of the buyer with the apparatus **114**, and the seller location data **602** includes data identifying a location of the seller with the component **110**. The buyer location data **600** and the seller location data **602** are acquired during the transaction for the component **110**, e.g., extracted from user profiles of each of the buyer and the seller and/or entered into a user interface as part of executing the transaction. In some situations, the buyer inputs the buyer location data **600** while completing the transaction and the seller inputs the seller location data **602** during generation of the component listing **202** associated with the component **110**. In some instances, the seller location data **602** is acquired directly from the component listing data **200**. The buyer location data **600** (e.g., destination) and the seller location data **602** (e.g., starting location or origin) are stored by the service provider system **102**. In one or more implementations, the service provider system **102** provides the route starting location and destination location to the location and routing module **444** of the robot **116** in coordination with the robot assistance request **308**.

[0131] The location and routing module **444** receives the buyer location data **600** and the seller location data **602** and generates a determined route **604** for the robot **116**, e.g., based on the location of the buyer and the location of the seller (block **1804** of FIG. **18**). In some cases, the determined route **604** includes a first stage from a starting location of the robot **116** (e.g., a warehouse or other previous location) to the location of the seller, a second stage from the location of the seller to the location of the buyer, and a third stage, such as from the location of the buyer to return to the starting location or to a next location for performing one or more of component verification, component transportation, or component installation.

[0132] FIGS. **7-9** illustrate examples of determined routes **604**. A deployment location **700** indicates the starting location of the robot **116**, e.g., the location of the robot **116** prior to initiation of travel of the robot **116** to a seller location **708**, e.g., a first location. In one or more implementations, this first location is associated with a seller, such as a seller's residence, a workplace of the seller, or a location where the seller has specified to meet the autonomous technician, to name just a few. In at least one scenario, the seller location, e.g., the first location, corresponds to a location associated with the platform **122**, such as a warehouse utilized by the platform **122**.

[0133] The robot **116**, indicated schematically in FIG. **7**, travels along a first stage **702** of the determined route **604** from the deployment location **700** toward the seller location **708**. The locomotion framework **426** supports the travel (e.g., by ground and/or by air) of the robot **116** along the determined route **604**. The locomotion controller **450** included by the locomotion framework **426** receives signals and other feedback from the sensors **400** and the location and routing module **444** (block **1806** of FIG. **18**), and the locomotion controller **450** issues commands to other components of the locomotion framework **426** to support the locomotion of the robot **116**.
[0134] In these examples, the robot **116** acquires the component **110** at the seller location **708**, e.g., responsive to verifying the component at the seller location **708**. The robot **116** then transports the component **110** to a buyer location **710**, e.g., a second location. In one or more implementations, this second location is associated with a buyer, such as a buyer's residence, a workplace of the buyer, a place where the buyer's apparatus has been stranded (e.g., on the side of the road), or a location where the buyer has otherwise specified to meet the autonomous technician for installing the component to the apparatus, to name just a few. In at least one scenario, the buyer location, e.g., the second location, corresponds to a location associated with the platform **122**, such as a shop utilized by the platform **122** to install components.
[0135] By way of example, the robot **116** stows the component **110** and travels with the component **110** along a second stage **704** of the determined route **604** from the seller location **708** to the buyer location **710** (block **1808** of FIG. **18**), as shown by FIG. **8**. After the robot **116** arrives at the buyer location **710** with the component **110**, the robot **116** (or another robot **116**) installs the component **110** to the apparatus **114** of the buyer. In some instances, the robot **116** communicates to the buyer that the robot **116** has arrived at the buyer location **710**, e.g., via communication with service provider system **102** which then communicates with buyer computing device **112** through platform **122**. In some scenarios, the buyer provides the robot **116** with temporary access to the apparatus **114**, such as via a code to an electronic lock, e.g., a door lock, a vehicle lock, or a garage panel. In one or more implementations, information for unlocking such electronic locks is included in the transaction data **306**. After installing the component **110** to the apparatus **114**, the robot **116** travels from the buyer location **710** to another location, such as by returning to the deployment location **700** along a third stage **706** of the determined route **604**, as shown in FIG. **9**. To support installation of the component **110** to the apparatus **114**, the robot **116** includes various devices, as described below.
[0136] FIG. **10** shows an implementation of the installation tool framework **434** and the component support framework **448** of the robot **116**. In the illustrated implementation, the installation tool framework **434** includes an installation control module **1000**, an appendage **1002**, and fasteners **1012**. The installation control module **1000** is configured to communicate with the service provider system **102** and the databases **106** via the network communication module **438**. The installation control module **1000** receives installation instructions from the installation protocol module **446** and performs operations using the appendage **1002**, the fasteners **1012**, and the component support framework **448** in accordance with installation instructions. Example operations are described further below with reference to FIG. **16**.
[0137] In one or more implementations, the appendage **1002** includes the dynamic toolhead **436**. In some implementations, the appendage **1002** is a rigid appendage, e.g., an arm. In other implementations, the appendage **1002** has a different structure, such as a flexible multi-jointed structure supporting bending and rotating or twisting of the appendage **1002**.
[0138] The dynamic toolhead **436** includes various tools, examples of which include but are not limited to sockets **1004**, pins **1006**, drivers **1008**, shapers **1010**, and so forth. Of course, the dynamic toolhead **436** may have different tools in variations. The robot **116** controls the dynamic toolhead **436** to employ one or more tools included by the dynamic toolhead **436** while other tools of the dynamic toolhead **436** are stowed, e.g., retracted. For instance, the installation control module **1000** commands an operation to be performed using the dynamic toolhead **436** while the

dynamic toolhead **436** has a particular socket of the sockets **1004** extended and with other sockets of the sockets **1004** stowed. Example implementations of the dynamic toolhead **436** are shown by FIGS. **11-14** and described below.

[0139] The component support framework **448** includes various devices that work either alone or in combination with the devices of the dynamic toolhead **436**. In the implementation shown, the component support framework **448** includes a grasping device **1014**, a clamping device **1016**, a support structure **1018**, and a lifting device **1020**. However, other devices are possible. The grasping device **1014** is a device, such as a pincer, used to grasp portions of other devices, such as the component **110** and/or the apparatus **114**. The clamping device **1016** is a device, such as a clamp, used to secure a position of other devices or temporarily connect two devices. The support structure **1018** is a frame or other structure, such as a platform, used to hold another device or apparatus. The lifting device **1020** is a device used to elevate a position of another device, e.g., lift another device relative to a ground surface. The various devices communicate electronically with the installation control module **1000**, in some implementations, to receive commands from the installation control module **1000**. For instance, the installation control module **1000** is able to issue instructions to the devices for movement of the devices, with movement performed via actuation of one or more actuators of the devices (e.g., solenoids, pistons, and so forth).

[0140] Referring collectively to FIGS. **11-14**, various implementations of the dynamic toolhead **436** are shown. The dynamic toolhead **436** is shown arranged at an end of the appendage **1002**. Movement of the appendage **1002** and the dynamic toolhead **436** is controlled via the installation control module **1000** as described above.

[0141] The dynamic toolhead **436** is shown including a tool set **1100**. The tool set **1100** includes tools such as the sockets **1004** described above. The tool set **1100** is shown including a first socket **1106**, a second socket **1108**, and a third socket **1110**. The sockets are retractable into the dynamic toolhead **436** along axis **1104**, as depicted by FIG. **11**, such that the sockets do not extend outward from a front end **1102** of the dynamic toolhead **436**. However, the installation control module **1000** can command the dynamic toolhead **436** to extend one or more of the sockets. Likewise, the installation control module **1000** can command the dynamic toolhead **436** to retract one or more of the sockets.

[0142] For instance, FIG. **12** shows the first socket **1106** in an extended position. The first socket **1106** has a larger first width **1200**. FIG. **13** shows the first socket **1106** in the retracted position and the second socket **1108** in the extended position. The second socket **1108** has a second width **1300** smaller than the first width **1200**. FIG. **14** shows the first socket **1106** and the second socket **1108** each in the retracted position, with the third socket **1110** in an extended position. The third socket **1110** has a third width **1400** that is smaller than each of the first width **1200** and the second width **1300**.

[0143] The installation control module **1000** controls which tools are extended to support interaction of the dynamic toolhead **436** with fasteners or other articles of various sizes. For instance, during installation of the component **110** to the apparatus **114**, the installation procedure may include adjustment of various nuts or bolts of different sizes. The installation control module **1000** can control the dynamic toolhead **436** to adjust which socket is in the extended position. The installation control module **1000** can then control the dynamic toolhead **436** to use the extended portion to loosen or tighten the nuts or bolts in accordance with the installation instructions.

[0144] Referring to FIG. **15**, an implementation of the robot **116** for verifying the condition of the apparatus **114** is shown. In some cases, the robot **116** verifies the condition of the apparatus **114** prior to installation of the component **110** to the apparatus **114**.

[0145] For example, the robot **116** detects the condition of the apparatus **114** (e.g., assesses the apparatus **114**) by acquiring data describing the apparatus **114** via the sensors **400** (block **1902** of FIG. **19**). A sensor output **1500** from the sensors **400** includes digital images of the apparatus **114** acquired via the camera **402**. The condition verification module **440** receives the sensor output

1500 and processes the sensor output **1500** via one or more machine learning models, such as machine learning model **1502**. In one or more implementations, the machine learning model **1502** is a deep neural network, or is or includes (e.g., in an ensemble of models) a large language model. The machine learning model **1502** is trained on data describing manufactured conditions of different apparatuses. In at least one implementation, the machine learning model **1502** is trained on image data describing various apparatuses, e.g., vehicles. The condition verification module **440** then employs the machine learning model **1502** to identify a make and model of the apparatus **114**, such as in situations in which the apparatus **114** is a vehicle.

[0146] The condition of the apparatus **114** as verified by the condition verification module **440** may also include a wear and/or modification status of the apparatus **114** in some instances. As one example, the condition verification module **440** determines via the machine learning model **1502** whether the apparatus **114** has been modified at some time following manufacture of the apparatus **114** based on the sensor output **1500**. By way of example, modification of the apparatus **114** may include installation of aftermarket components to the apparatus **114**, modification of components of the apparatus **114**, removal of components from the apparatus **114**, and so forth.

[0147] The condition verification module **440** outputs an apparatus verification result **1504**, such as to the service provider system **102**. Based on a content of the apparatus verification result **1504**, the service provider system **102** performs various operations. In a scenario in which the apparatus verification result **1504** indicates that the apparatus **114** has not been modified relative to a manufactured condition of the apparatus **114**, the service provider system **102** communicates with the robot **116** to instruct the robot **116** to proceed with installation of the component **110** to the apparatus **114**. In a different scenario in which the apparatus verification result **1504** indicates that the apparatus **114** has been modified post-manufacture, the service provider system **102** communicates with the robot **116** to provide updated instructions to the robot **116**. The updated instructions may include, for instance, an updated installation procedure to be performed by the robot **116**, where the updated installation procedure accounts for modifications that have been made to the apparatus **114**. In at least one implementation, the robot **116** is configured to modify installation instructions on-the-fly via the installation protocol module **446** using another learning model, as described below with reference to FIG. **16**. Alternatively, in a scenario where the apparatus verification result **1504** indicates that the apparatus **114** has been modified post-manufacture or its compatibility otherwise cannot be verified, the service provider system **102** may communicate an instruction to the robot **116** to cancel installation of the component **110** to the apparatus **114**.

[0148] FIG. **16** depicts an example implementation of the robot **116** performing installation of the component **110** to the apparatus **114**. In this example, the installation protocol module **446** of the robot **116** receives the apparatus verification result **1504** and the component verification result **508**. Based on the content of those results, the robot **116** communicates with the databases **106** to retrieve various installation protocols (block **1904** of FIG. **19**). In at least one example, the databases **106** include one or more installation protocol libraries, such as protocol library **1600**, and one or more application programming interfaces (APIs), such as application programming interface **1602**. The installation protocol module **446** employs a machine learning model **1606**, which is trained on data describing a plurality of installation protocols, to process the apparatus verification result **1504** and the component verification result **508**. In at least one implementation, the machine learning model is a neural network, e.g., a deep neural network.

[0149] In at least one implementation, an output of the machine learning model **1606** indicates one or more protocols and/or APIs to be retrieved from databases **106**. The installation protocol module **446** retrieves the one or more protocols and/or APIs and provides the retrieved protocols and/or APIs to the machine learning model **1606** (block **1906** of FIG. **19**). The machine learning model **1606** then electronically communicates installation instructions **1604** to the installation control module **1000** based on the retrieved information. The installation control module **1000** controls the dynamic toolhead **436** and other components of the robot **116** in accordance with the installation instructions **1604** to install the component **110** to the apparatus **114** (block **1908** of FIG. **19**).

[0150] In a scenario where the apparatus verification result **1504** indicates that the detected condition of the apparatus **114** matches the manufactured condition of the apparatus **114**, the installation protocol module **446** retrieves a first set of protocols from the protocol library **1600** and/or one or more APIs, e.g., the application programming interface **1602**. The first set of protocols and/or APIs are used by the robot **116** for installation of the component **110** to the apparatus **114** during conditions in which the apparatus **114** has not been modified post-manufacture. Modification post-manufacture refers to installation of components or the performance of other modifications to the apparatus **114** that may interfere with installation of the component **110**.

[0151] However, in a scenario in which the apparatus verification result **1504** indicates that the apparatus **114** has been modified post-manufacture, the installation protocol module **446** retrieves a second set of protocols and/or APIs. The second set of protocols or APIs include differences in the installation procedure based on the modifications that have been made to the apparatus **114**. For instance, modification of the apparatus **114** with an aftermarket device can alter access to other portions of the apparatus **114**, e.g., clearances within the apparatus **114** and other attributes. The second set of protocols or APIs provides the robot **116** with instructions for navigating around aftermarket devices installed to the apparatus **114** (and/or removing the aftermarket devices) in order to install the component **110** to the apparatus **114**.

[0152] The installation protocol module **446** further receives signals from the sensors **400** of the robot **116** and adjusts the installation instructions **1604** based on the received signals. The signals may include electronic signals such as image data from the camera **402** and audio data from the microphone **404**. The signals may further include, for example, voltage, current, and/or resistance measurements from the multimeter **408**, weight measurements from the scale **412**, and/or optical measurements from the spectrometer **416**, among others.

[0153] In one example scenario, the installation protocol module **446** provides the installation instructions **1604** to the installation control module **1000**. The installation control module **1000** then controls the dynamic toolhead **436** according to the installation instructions **1604**. The installation instructions **1604** include instructions for performing an operation of removing a bolt from the apparatus **114**. According to information included in the protocol provided to the installation protocol module **446**, the bolt has a particular head diameter, e.g., ten millimeters. The installation protocol module **446** identifies the bolt to be removed via the machine learning model **1606** which receives image data from the camera **402** of the sensors **400**, and the installation protocol module **446** detects a shape of the bolt based on the image data (block **1910** of FIG. **19**).

[0154] However, in detecting the shape of the bolt, the installation protocol module **446** determines that the size of the head of the bolt is larger than the diameter described by the protocol. As one example, the detected diameter is twenty millimeters instead of ten millimeters. In response to this determination, the installation protocol module **446** adjusts operation of the dynamic toolhead **436** based on the detected shape (e.g., diameter) of the bolt (block **1912** of FIG. **19**). The installation protocol module **446** outputs updated installation instructions that control the dynamic toolhead **436** to utilize a socket sized appropriately to the twenty-millimeter head (e.g., the second socket **1108** shown by FIG. **13**) instead of a socket sized to the ten millimeter head (e.g., the third socket **1110** shown by FIG. **14**).

[0155] The above-described scenario is one example of on-the-fly modification of installation instructions performed by the robot **116**. However, the robot **116** is not limited to adjustment of the instructions based on bolt size or bolt shape. In other instances, the installation instructions are adjusted responsive to detection of other parameters. Such adjustments to the installation instructions include, for instance, adjusting a torque applied to the apparatus **114** by the dynamic toolhead **436** based on a detected weight or density of a portion of the apparatus **114**, e.g., as measured by the sensors **400**. The robot **116** may adjust the installation instructions based on detecting a variety of conditions in variations.

[0156] In one or more scenarios, examples of which are described above, the robot **116** employs the installation tool framework **434** to remove one or more components from the apparatus **114** (or at least partially disassemble them) prior to installing the component **110**, e.g., to replace the one or more components with the component **110**. In some implementations, the robot **116** controls the dynamic toolhead **436** to remove the one or more components in accordance with the protocols and/or APIs described above. In at least one implementation, the installation protocol module **446** receives signals from the sensors **400** of the robot **116** and determines the location and/or arrangement of one or more components to be removed from the apparatus **114** prior to installation of the component **110**. As a result, the installation protocol module **446** updates the installation instructions to control the dynamic toolhead **436** and/or other devices of the installation tool framework **434** to remove the one or more components and install the component **110**.

[0157] In some implementations, the robot **116** is selected from among a plurality of robots forming the autonomous technician **120** based on particular characteristics of the robot **116** that increase an ease of installation of the component **110** to the apparatus **114**. In one scenario, the autonomous technician **120** includes several robots including a configuration similar to the robot **116**, but each robot has a different overall profile or form factor. A first robot for instance has a lower overall height than the other robots, while a second robot has a narrower diameter than the other robots. Depending on the attributes of the component **110** to be installed to the apparatus **114** and/or attributes of the apparatus **114**, the first robot or the second robot is selected for deployment and installation of the component **110**. If the component **110** is to be installed to an underside of the apparatus **114**, for example, the first robot may be deployed to increase an ease with which the robot fits beneath the apparatus **114** to perform installation operations. However, if the component **110** is to be installed to an interior space of the apparatus **114** with reduced clearances, the second robot is deployed to increase an ease with which the robot fits within the interior of the apparatus **114**.

[0158] FIG. **17** depicts a procedure in an example implementation of verifying a component for an apparatus via an autonomous technician.

[0159] A component is assessed at a seller location via a robot using one or more sensors (block **1702**). In accordance with the principles described herein, assessing the component includes scanning (e.g., measuring, imaging, etc.) the component via the one or more sensors of the robot. By way of example, one or more of the robots **116** of the autonomous technician **120** assess the component **110** at a seller location, e.g., the seller location **708**.

[0160] An identifier of the component is determined based on an output of the one or more sensors during the assessing using a component recognition machine learning model of the robot (block **1704**). In accordance with the principles described herein, determining the identifier of the component using the component recognition machine learning model includes detecting the identifier based on similarity between the identifier and a plurality of known identifiers. The similarity is determined via the machine learning model, where the machine learning model is trained on data describing the plurality of known identifiers. By way of example, one or more of the robots **116** of the autonomous technician **120** determine the identifier **510** of the component **110** based on output from one or more of the sensors **400** using the machine learning model **506**.

[0161] A match is determined between the identifier and the apparatus (block **1706**). In accordance with the principles described herein, determining the match between the identifier and the apparatus includes comparing the identifier to the known reference identifiers, where the known reference identifiers are associated with apparatuses in one or more compatibility libraries and/or databases. By way of example, one or more robots **116** of the autonomous technician **120** determine a match between the identifier **510** and the apparatus **114** by comparing the identifier **510** to known identifiers included in UPC database **500**, MPN database **502**, and/or compatibility library **504** via the machine learning model **506**.

[0162] A component verification result is output (block **1708**). In accordance with the principles described herein, outputting the component verification result includes communicating the component verification result electronically to a service provider system. By way of example, one or more robots **116** of the autonomous technician **120** output the component verification result **508** and communicate the component verification result **508** to service provider system **102**, where the component verification result **508** indicates whether the component **110** is compatible for installation to the apparatus **114**.

[0163] FIG. **18** depicts a procedure in an example implementation of transporting a component for an apparatus from a seller location to a buyer location via an autonomous technician.

[0164] Transaction data associated with the component is received, the transaction data including buyer location data (block **1802**). In accordance with the principles described herein, receiving the transaction data associated with the component includes acquiring the transaction data by one or more robots of an autonomous technician from a service provider system. By way of example, one or more robots **116** of the autonomous technician **120** receive the transaction data **306** through electronic communication with the service provider system **102**.

[0165] A route to the buyer location is generated via the location and routing module based on the buyer location data (block **1804**). In accordance with the principles described herein, generating the route to the buyer location based on the buyer location data includes generating the route from a seller location to the buyer location. By way of example, one or more robots **116** of the autonomous technician **120** generate the determined route **604** from the seller location **708** to the buyer location **710** based on the buyer location data **600** included in the transaction data **306**.

[0166] Feedback is received from the one or more sensors, and commands are issued to the locomotion framework based on the received feedback (block **1806**). In accordance with the principles described herein, receiving feedback from the one or more sensors and issuing commands to the locomotion framework based on the received feedback includes detecting an environment of one or more robots of the autonomous technician and issuing commands to the locomotion framework for navigating the detected environment. Detecting the environment includes, but is not limited to, detecting a terrain around the one or more robots, detecting weather conditions around the one or more robots, and detecting obstacles and/or pathways around the one or more robots. By way of example, one or more robots **116** of the autonomous technician **120** receive feedback from one or more of the sensors **400** and issue commands to locomotion framework **426** through locomotion controller **450** based on the received feedback.

[0167] The component is transported along the route to the buyer location (block **1808**). In accordance with the principles described herein, transporting the component along the route to the buyer location includes stowing the component via the one or more robots of the autonomous technician and transporting the component along the route by traveling the route via the one or more robots. By way of example, one or more robots **116** of the autonomous technician **120** acquire the component **110** at the seller location **708** and travel along the determined route **604** to transport the component **110** from the seller location **708** to the buyer location **710**.

[0168] FIG. **19** depicts a procedure in an example implementation of installing a component for an apparatus via an autonomous technician.

[0169] A condition of the apparatus is assessed at the buyer location via the robot using one or more sensors (block **1902**). In accordance with the principles described herein, assessing the condition of the apparatus includes determining a wear and/or modification status of the apparatus based on an output of the one or more sensors. By way of example, one or more robots **116** of the autonomous technician **120** assess the condition of the apparatus **114** by scanning the apparatus **114** via one or more of the sensors **400**. Scanning the apparatus **114** includes, for example, employing one or more of camera **402**, microscope **410**, and spectrometer **416** to generate sensor output **1500** including data (e.g., image data) data describing the apparatus **114**. The sensor output **1500** is processed by machine learning model **1502** to assess the condition of the apparatus **114**, e.g., generate apparatus verification result **1504**.

[0170] Installation protocols and/or APIs are determined based on condition of the apparatus and condition of the component (block **1904**). In accordance with the principles described herein, determining installation protocols and/or APIs based on the condition of the apparatus and the condition of the component includes processing data describing the condition of the apparatus and data describing the condition of the component via a machine learning model, and determining the installation protocols and/or APIs according to an output of the machine learning model. By way of example, one or more robots **116** of the autonomous technician **120** process the apparatus verification result **1504** describing the condition of apparatus **114** and the component verification result **508** describing the condition of component **110** via machine learning model **1606**. The machine learning model **1606** determines installation protocols and/or APIs to be acquired by the one or more robots **116** based on the apparatus verification result **1504** and the component verification result **508**.

[0171] The installation protocols and/or APIs are provided to an installation procedure machine learning model (block **1906**). In accordance with the principles described herein, the determined installation protocols and/or APIs are acquired from one or more databases. By way of example, one or more robots **116** of the autonomous technician **120** acquire the determined installation protocols from protocol library **1600** stored in databases **106** and/or acquire the APIs, such as application programming interface **1602**, from databases **106**. The acquired installation protocols and/or APIs are provided to machine learning model **1606**.

[0172] The component is installed to the apparatus via the robot using the installation procedure machine learning model (block **1908**). In accordance with the principles described herein, installing the component to the apparatus via the robot includes performing operations via the robot in accordance with installation instructions output by the installation procedure machine learning model. By way of example, one or more of the robots **116** of the autonomous technician **120** are controlled to perform operations included in installation instructions **1604** output by the machine learning model **1606**. The installation instructions **1604** are executed by the one or more robots, e.g., through commands issued by installation control module **1000**, to control operation of the installation tool framework **434** and other components of the one or more robots to install the component **110** to the apparatus **114**.

[0173] A shape of a fastener to be rotated during the installation is detected (block **1910**). In accordance with the principles described herein, detecting the shape of the fastener to be rotated is one operation that may be performed during the installation of the component to the apparatus. By way of example, one or more robots **116** of the autonomous technician **120** detect the shape of the fastener, e.g., a fastener included by the apparatus **114**, based on an output of one or more of the sensors **400**. The shape of the fastener is determined by a machine learning model, such as machine learning model **1502**, with data describing the determined shape communicated to the machine learning model **1606**. Based on the determined shape, the machine learning model **1606** updates the installation instructions **1604** (e.g., if the determined shape is different than an expected shape, where the expected shape is described by one or more of the acquired installation protocols and/or APIs) or maintains the installation instructions **1604** (e.g., if the determined shape matches the expected shape).

[0174] A dynamic toolhead is adjusted based on the detected shape of the fastener (block **1912**). In accordance with the principles described herein, adjusting the dynamic toolhead based on the detected shape of the fastener includes extending one or more tools included by the dynamic toolhead to engage the tools with the fastener, e.g., for rotation of the fastener. By way of example, dynamic toolhead **436** of one of the robots **116** of the autonomous technician **120** includes a plurality of sockets **1004**, and the dynamic toolhead **436** is adjusted by the robot **116** such that the first socket **1106** is in the extended position while other sockets included by the dynamic toolhead

436 are in the retracted position. With the first socket **1106** in the extended position, the dynamic toolhead **436** engages the first socket **1106** with the fastener for rotation of the fastener (e.g., for removal of the fastener from the apparatus **114** or the component **110**, or tightening of the fastener to the apparatus **114** or the component **110**).

[0175] FIG. **20** depicts a procedure **2000** in an example implementation of an autonomous technician system for component handling and installation.

[0176] A component is verified at a seller location for an apparatus that is located at a buyer location (block **2002**). In accordance with the principles described herein, verification of the component includes verifying compatibility of the component with the apparatus. By way of example, one or more of the robots **116** of the autonomous technician **120** verifies the component **110** at a buyer location, e.g., the buyer location **710**. In accordance with the described techniques, the one or more robots **116** verify compatibility of the component **110** with the apparatus **114**.

[0177] The component is transported to the buyer location (block **2004**). By way of example, one or more of the robots **116** of the autonomous technician **120** transports the component **110** to the buyer location **710**.

[0178] The component is installed in the apparatus (block **2006**). By way of example, one or more of the robots **116** of the autonomous technician **120** installs the component **110** in the apparatus **114**.

Example System and Device

[0179] Referring to FIG. **21**, an example system **2100** is depicted that includes an example computing device that is representative of one or more computing systems and/or devices that are usable to implement the various techniques described herein. This is illustrated through inclusion of the service provider system **102** implementing the robot **116**. Computing device **2120** includes, for example, a server of the service provider system **102**, a device associated with a client (e.g., a client device), an on-chip system, and/or any other suitable computing device or computing system.

[0180] The example computing device **2120** as illustrated includes a processing system **2102**, one or more computer-readable media **2106**, and one or more input/output interfaces **2110** (I/O interfaces) that are communicatively coupled, one to another. Although not shown, the computing device **2120** further includes a system bus or other data and command transfer system that couples the various components, one to another. For example, a system bus includes any one or combination of different bus structures, such as a memory bus or memory controller, a peripheral bus, a universal serial bus, and/or a processor or local bus that utilizes any of a variety of bus architectures. A variety of other examples are also contemplated, such as control and data lines.

[0181] The processing system **2102** is representative of functionality to perform one or more operations using hardware. Accordingly, the processing system **2102** is illustrated as including hardware elements **2104** that are configured as processors, functional blocks, and so forth. This includes example implementations in hardware as a system specific integrated circuit or other logic device formed using one or more semiconductors. The hardware elements **2104** are not limited by the materials from which they are formed or the processing mechanisms employed therein. For example, processors are comprised of semiconductor(s) and/or transistors (e.g., electronic integrated circuits (ICs)). In such a context, processor-executable instructions are, for example, electronically-executable instructions.

[0182] The computer-readable media **2106** is illustrated as including memory/storage **2108**. The memory/storage **2108** represents memory/storage capacity associated with one or more computer-readable media. In one example, the memory/storage **2108** includes volatile media (such as random access memory (RAM)) and/or nonvolatile media (such as read only memory (ROM), Flash memory, optical disks, magnetic disks, and so forth). In another example, the memory/storage **2108** includes fixed media (e.g., RAM, ROM, a fixed hard drive, and so on) as well as removable media (e.g., Flash memory, a removable hard drive, an optical disc, and so forth). The computer-readable media **2106** is configurable in a variety of other ways as further described below.

[0183] The input/output interface(s) **2110** are representative of functionality to allow user input to enter commands and information to the computing device **2120**, and also allow information to be presented and/or other components or devices using various input/output devices. Examples of input devices include a keyboard, a cursor control device (e.g., a mouse), a microphone, a scanner, touch functionality (e.g., capacitive or other sensors that are configured to detect physical touch), a camera (e.g., which employs visible or non-visible wavelengths such as infrared frequencies to recognize movement as gestures that do not involve touch), and so forth. Examples of output devices include a display device (e.g., a monitor or projector), speakers, a printer, a network card, tactile-response device, and so forth. Thus, the computing device **2120** is configurable in a variety of ways as further described below to support user interaction.
[0184] Various techniques are described herein in the general context of software, hardware elements, or program modules. Generally, such modules include routines, programs, objects, elements, components, data structures, and so forth that perform particular tasks or implement particular abstract data types. The terms "module," "functionality," and "component" as used herein generally represent software, firmware, hardware, or a combination thereof. The features of the techniques described herein are platform-independent, meaning that the techniques are implementable on a variety of commercial computing platforms having a variety of processors.
[0185] Implementations of the described modules and techniques are storable on or transmitted across some form of computer-readable media. For example, the computer-readable media includes a variety of media that is accessible to the service provider system **102**. By way of example, and not limitation, computer-readable media includes "computer-readable storage media" and "computer-readable signal media."
[0186] "Computer-readable storage media" refers to media and/or devices that enable persistent and/or non-transitory storage of information in contrast to mere signal transmission, carrier waves, or signals per se. Thus, computer-readable storage media refers to non-signal bearing media. The one-or-more computer-readable storage media includes hardware such as volatile and non-volatile, removable and non-removable media and/or storage devices implemented in a method or technology suitable for storage of information such as computer readable instructions, data structures, program modules, logic elements/circuits, or other data. Examples of computer-readable storage media include, but are not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical storage, hard disks, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or other storage device, tangible media, or article of manufacture suitable to store the desired information and which are accessible to a computer.
[0187] "Computer-readable signal media" refers to a signal-bearing medium that is configured to transmit instructions to the hardware of the computing device **2120**, such as via a network. Signal media typically embodies computer readable instructions, data structures, program modules, or other data in a modulated data signal, such as carrier waves, data signals, or other transport mechanism. Signal media also include any information delivery media. The term "modulated data signal" means a signal that has one or more of its characteristics set or changed in such a manner as to encode information in the signal. By way of example, and not limitation, communication media include wired media such as a wired network or direct-wired connection, and wireless media such as acoustic, RF, infrared, and other wireless media.
[0188] As previously described, the hardware elements **2104** and the computer-readable media **2106** are representative of modules, programmable device logic and/or fixed device logic implemented in a hardware form that is employable in some implementations to implement at least some aspects of the techniques described herein, such as to perform one or more instructions. Hardware includes components of an integrated circuit or on-chip system, a system-specific integrated circuit (ASIC), a field-programmable gate array (FPGA), a complex programmable logic device (CPLD), and other implementations in silicon or other hardware. In this context, hardware

operates as a computing device that performs program tasks defined by instructions and/or logic embodied by the hardware as well as a hardware utilized to store instructions for execution, e.g., the computer-readable storage media described previously.

[0189] Combinations of the foregoing are also employable to implement various techniques described herein. Accordingly, software, hardware, or executable modules are implementable as one or more instructions and/or logic embodied on some form of computer-readable storage media and/or by one or more of the hardware elements **2104**. For example, the computing device **2120** is configured to implement particular instructions and/or functions corresponding to the software and/or hardware modules. Accordingly, implementation of a module that is executable by the computing device **2120** as software is achieved at least partially in hardware, e.g., through use of computer-readable storage media and/or the hardware elements **2104** of the processing system **2102**. The instructions and/or functions are executable/operable by one or more articles of manufacture (for example, one or more computing devices such as computing device **2120** and/or processing systems such as processing system **2102**) to implement techniques, modules, and examples described herein.

[0190] The techniques described herein are supportable by various configurations of the computing device **2120** and are not limited to the specific examples of the techniques described herein. This functionality is also implementable entirely or partially through use of a distributed system, such as over a “cloud” **2112** as described below.

[0191] The cloud **2112** includes and/or is representative of the platform **122** for resources **2114**. The platform **122** abstracts underlying functionality of hardware (e.g., servers) and software resources of the cloud **2112**. For example, the resources **2114** include systems and/or data that are utilized while computer processing is executed on servers that are remote from the computing device **2120**. In some examples, the resources **2114** also include services provided over the Internet and/or through a subscriber network, such as a cellular or Wi-Fi network.

[0192] The platform **122** abstracts the resources **2114** and functions to connect the computing device **2120** with other computing devices. In some examples, the platform **122** also serves to abstract scaling of resources to provide a corresponding level of scale to encountered demand for the resources that are implemented via the platform **122**. Accordingly, in an interconnected device implementation, implementation of functionality described herein is distributable throughout the system **2100**. For example, the functionality is implementable in part on the computing device **2120** as well as via the platform **122** that abstracts the functionality of the cloud **2112**.

[0193] The autonomous technician management module **2118** included by the service provider system **102** is utilized by the service provider system **102** for control of communications between the service provider system **102** and the autonomous technician **120**, e.g., to support operations such as deployment of the robot **116**. For example, the service provider system **102** receives the robot assistance request **308** described above with reference to FIG. **3** via the autonomous technician management module **2118**. Responsive to receiving the robot assistance request **308**, the service provider system **102** utilizes the autonomous technician management module **2118** to communicate with one or more robots of the autonomous technician **120** for deployment of the one or more robots to perform operations including component condition verification, component transport, and component installation as described herein. Further, during conditions in which a robot such as the robot **116** communicates with the databases **106** to acquire installation protocols or other data as described herein, such communications are routed through the autonomous technician management module **2118** of the service provider system **102** at least in some implementations. The service provider system **102** then provides the requested data from the databases **106** to the robot by communicating electronically with the robot via the autonomous technician management module **2118**. The autonomous technician management module **2118**, in some implementations, provides wired and/or wireless communication capabilities between the service provider system **102** and the robots of the autonomous technician **120** for issuing instructions to the robots and providing data and other information to the robots as described herein.

CONCLUSION

[0194] Although the systems and techniques have been described in language specific to structural features and/or methodological acts, it is to be understood that the systems and techniques defined in the appended claims are not necessarily limited to the specific features or acts described. Rather, the specific features and acts are disclosed as example forms of implementing the claimed subject matter. Further, various different examples are described and it is to be appreciated that each described example is implementable independently or in connection with one or more other described examples.

Claims

1. A system of one or more robots that implement an autonomous technician, the system comprising: the autonomous technician configured to perform operations comprising: verifying a component at a first location for an apparatus that is located at a second location, including verifying compatibility of the component with the apparatus; transporting the component to the second location; and installing the component in the apparatus.

2. The system as described in claim 1, wherein the autonomous technician includes one or more sensors, and verifying compatibility of the component with the apparatus includes: assessing the component at the first location using the one or more sensors; determining an identifier of the component based on an output of the one or more sensors during the assessing; and matching the identifier to the apparatus.

3. The system as described in claim 1, wherein the autonomous technician includes a dynamic toolhead, and installing the component in the apparatus with the autonomous technician includes: detecting a shape of a fastener to be rotated during the installing; and adjusting the dynamic toolhead based on the detected shape of the fastener.

4. The system as described in claim 1, wherein the autonomous technician includes: one or more sensors; a locomotion framework; and a reasoning module configured to receive feedback from the one or more sensors and issue commands to the locomotion framework based on the received feedback.

5. The system as described in claim 2, wherein the autonomous technician includes a component recognition machine learning model stored in memory, the component recognition machine learning model trained on data including a plurality of component identifiers, and the determining of the identifier of the component is performed using the component recognition machine learning model.

6. The system as described in claim 1, wherein the autonomous technician includes an installation procedure machine learning model stored in memory, the installation procedure machine learning model trained on data including a plurality of installation instructions, and installing the component in the apparatus is performed using the installation procedure machine learning model.

7. The system as described in claim 1, wherein the autonomous technician includes a component recognition machine learning model and an installation procedure machine learning model, the component recognition machine learning model trained on data including a plurality of component identifiers and the installation procedure machine learning model trained on data including a plurality of installation instructions, and an output of the component recognition machine learning model is an input of the installation procedure machine learning model.

8. The system as described in claim 1, wherein the autonomous technician includes a location and routing module, and transporting the component to the second location includes: receiving transaction data associated with the component, the transaction data including location data describing the second location; generating a route to the second location via the location and

routing module based on the location data; and transporting the component along the route to the second location.
9. The system as described in claim 1, wherein the autonomous technician includes a first robot configured to perform the verifying of the component at the first location for the apparatus that is located at the second location, and a second robot configured to perform the installing of the component in the apparatus.
10. The system as described in claim 1, wherein the autonomous technician includes a network communication module configured to retrieve component installation data via wired or wireless communications responsive to determining an identifier of the component using one or more sensors.
11. The system as described in claim 10, wherein the network communication module retrieves the component installation data from a service provider system including a listing of the component.
12. The system as described in claim 10, wherein the first location is associated with a seller of the component and the second location is associated with a buyer of the component.
13. A method implemented by one or more robots of an autonomous technician, the method comprising: verifying, by the autonomous technician, a component at a first location for an apparatus that is located at a second location; transporting, by the autonomous technician, the component to the second location; and installing, by the autonomous technician, the component in the apparatus.
14. The method as described in claim 13, wherein verifying the component at the first location for the apparatus that is located at the second location includes: assessing the component, by the autonomous technician, using one or more sensors of the autonomous technician; determining, by the autonomous technician, an identifier of the component based on an output of the one or more sensors during the assessing; and matching, by the autonomous technician, the identifier to the apparatus.
15. The method as described in claim 13, wherein transporting the component to the second location includes: receiving, by the autonomous technician, location data describing the second location; generating, by the autonomous technician, a route to the second location based on the location data; and transporting, by the autonomous technician, the component along the route to the second location.
16. The method as described in claim 13, wherein verifying the component at the first location for the apparatus that is located at the second location is performed by the autonomous technician using a first machine learning model of the autonomous technician, and installing the component in the apparatus is performed by the autonomous technician using a second machine learning model of the autonomous technician.
17. The method as described in claim 16, wherein the first machine learning model is trained on data describing a plurality of known component identifiers, and the second machine learning model is trained on data describing a plurality of installation protocols.
18. The method as described in claim 13, further comprising: verifying, by the autonomous technician, a condition of the apparatus that is located at the second location by: acquiring, by the autonomous technician, image data describing the apparatus using one or more sensors of the autonomous technician; detecting, by the autonomous technician, the condition of the apparatus based on the image data; and determining, by the autonomous technician, whether the detected condition of the apparatus matches a described condition of the apparatus using a machine learning model.
19. One or more computer-readable storage media storing executable instructions which, responsive to execution by an autonomous technician implemented by one or more robots, cause the autonomous technician to perform operations comprising: verifying a component at a first location for an apparatus that is located at a second location, including verifying compatibility of the component with the apparatus; transporting the component to the second location; and

installing the component in the apparatus.

20. The one or more computer-readable storage media as described in claim 19, the operations further comprising: inputting data describing the component to a first machine learning model for the verifying of the component; generating a route from the first location to the second location to be travelled by the autonomous technician for the transporting of the component to the second location; inputting data describing one or more installation protocols to a second machine learning model for the installing of the component in the apparatus; and verifying a condition of the apparatus that is located at the second location by inputting data describing the apparatus to a third machine learning model.