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Kwak et al.

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(54) **SYSTEMS AND METHODS USING IMAGE RECOGNITION PROCESSES AND DETERMINED DEVICE ORIENTATION FOR IMPROVED OPERATION OF A LAUNDRY APPLIANCE**

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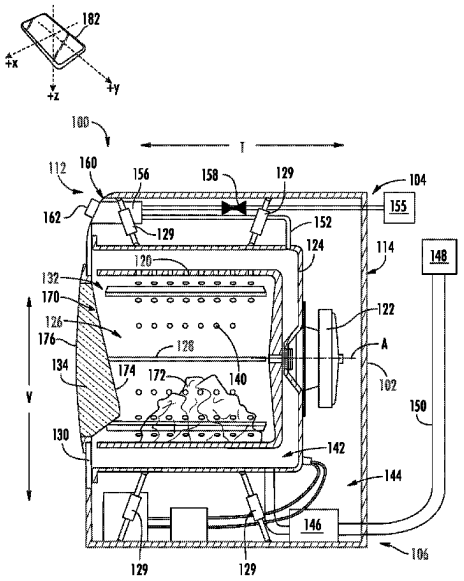
(57) **ABSTRACT**

A method of operating a washing machine appliance may include obtaining one or more images of the washing machine appliance from a camera assembly of a remote device spaced apart from the cabinet. The method may also include receiving a plurality of angle readings from the remote device and determining a position of the remote device relative to the washing machine appliance based on the plurality of angle readings. The method may further include determining a set camera angle for the camera assembly is met based on the determined position of the remote device. The method may still further include analyzing at least one obtained image using a machine learning image recognition process, estimating a load attribute of a load of clothes within the washing machine appliance based on the analysis, and directing a wash cycle within the washing machine appliance based on the estimated load attribute.

16 Claims, 5 Drawing Sheets



(51) **Int. Cl.**

G06T 7/70	(2017.01)
D06F 103/02	(2020.01)
D06F 103/40	(2020.01)

(52) **U.S. Cl.**

CPC *D06F 2103/40* (2020.02); *G06T 2207/20084* (2013.01); *G06T 2207/30232* (2013.01); *G06T 2207/30244* (2013.01)

(58) **Field of Classification Search**

CPC . G06T 2207/30244; G06T 2207/10024; G06T 2207/0008; G06T 2207/20081; G06T 2207/30164

See application file for complete search history.

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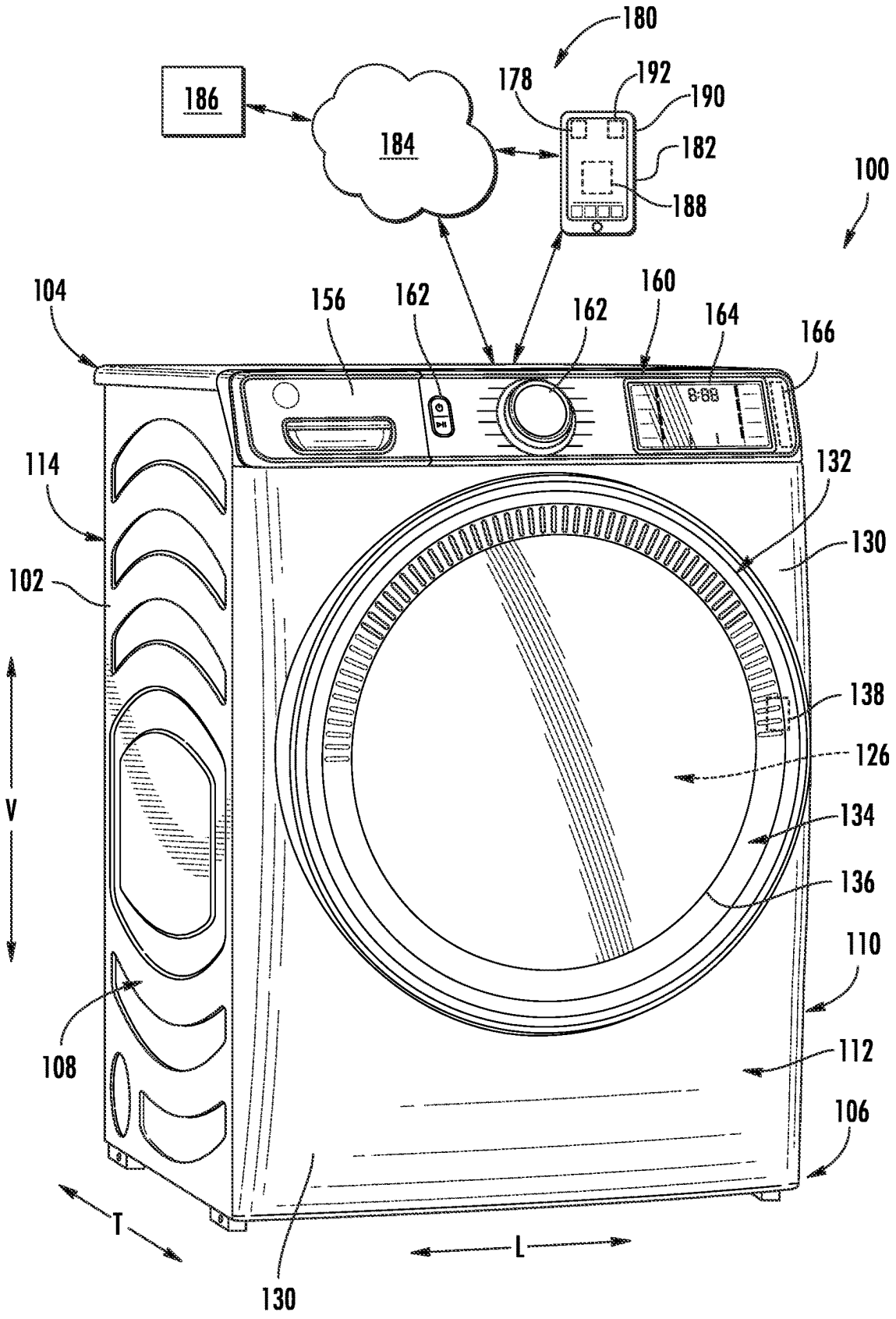
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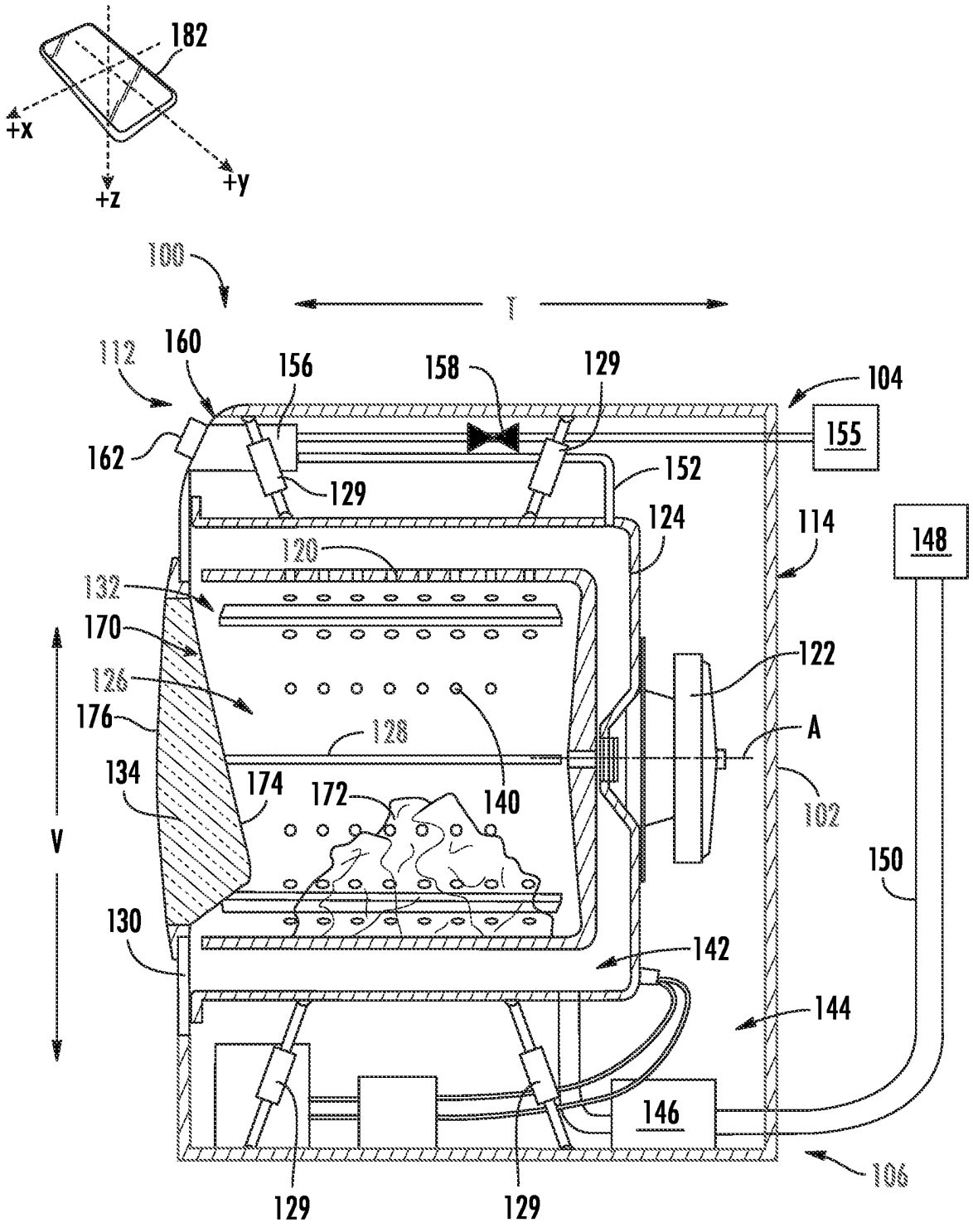
FIG. 1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132
170
122
126
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129

FIG. 2

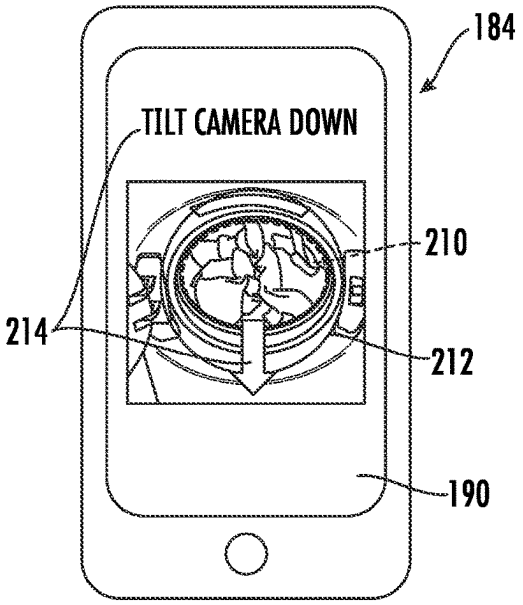

FIG. 3A

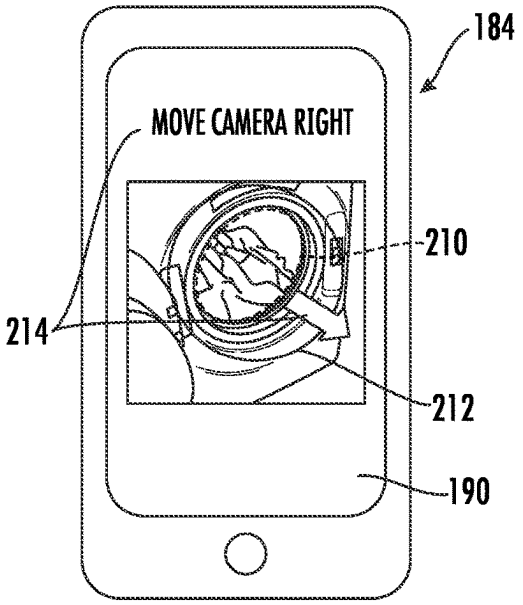

FIG. 3B

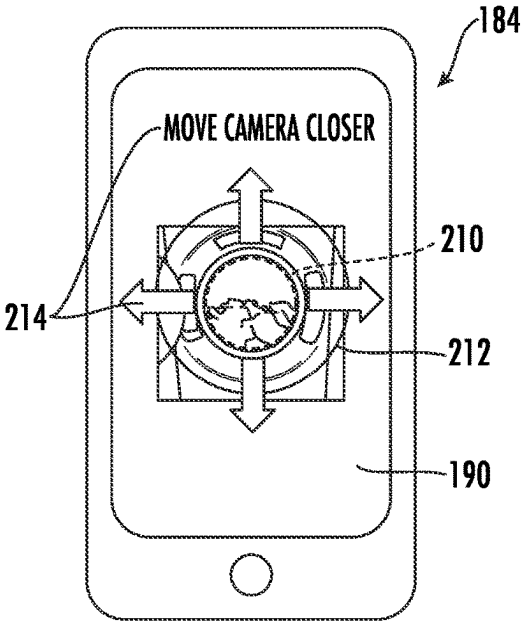

FIG. 3C

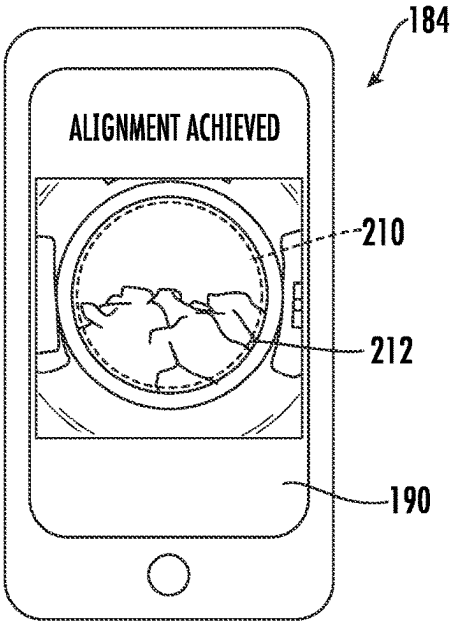

FIG. 3D

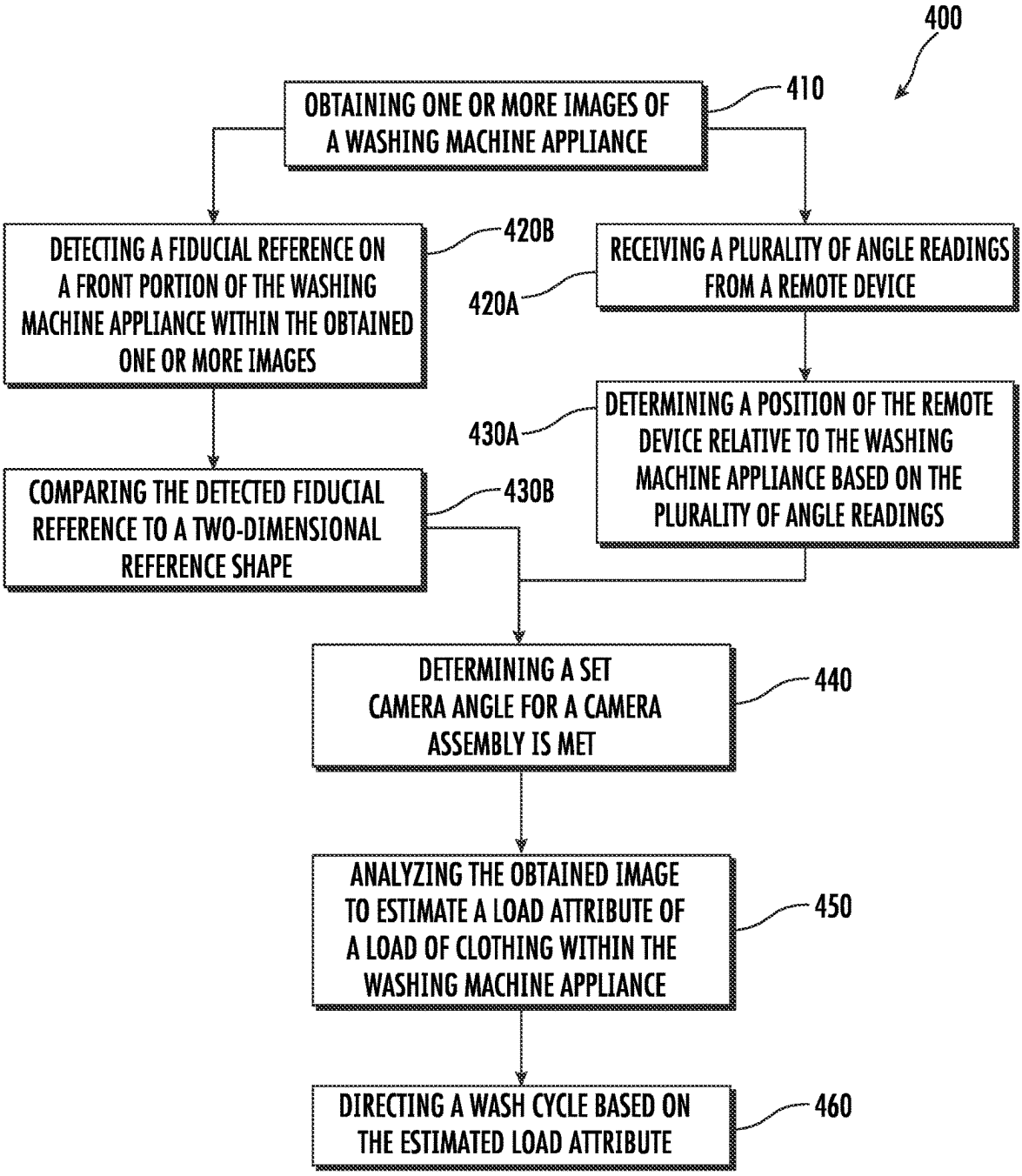
400
OBTAINING ONE OR MORE IMAGES OF A WASHING MACHINE APPLIANCE
410
DETECTING A FIDUCIAL REFERENCE ON A FRONT PORTION OF THE WASHING MACHINE APPLIANCE WITHIN THE OBTAINED ONE OR MORE IMAGES
420B
RECEIVING A PLURALITY OF ANGLE READINGS FROM A REMOTE DEVICE
420A
DETERMINING A POSITION OF THE REMOTE DEVICE RELATIVE TO THE WASHING MACHINE APPLIANCE BASED ON THE PLURALITY OF ANGLE READINGS
430A
COMPARING THE DETECTED FIDUCIAL REFERENCE TO A TWO-DIMENSIONAL REFERENCE SHAPE
430B
DETERMINING A SET CAMERA ANGLE FOR A CAMERA ASSEMBLY IS MET
440
ANALYZING THE OBTAINED IMAGE TO ESTIMATE A LOAD ATTRIBUTE OF A LOAD OF CLOTHING WITHIN THE WASHING MACHINE APPLIANCE
450
DIRECTING A WASH CYCLE BASED ON THE ESTIMATED LOAD ATTRIBUTE
460

FIG. 4

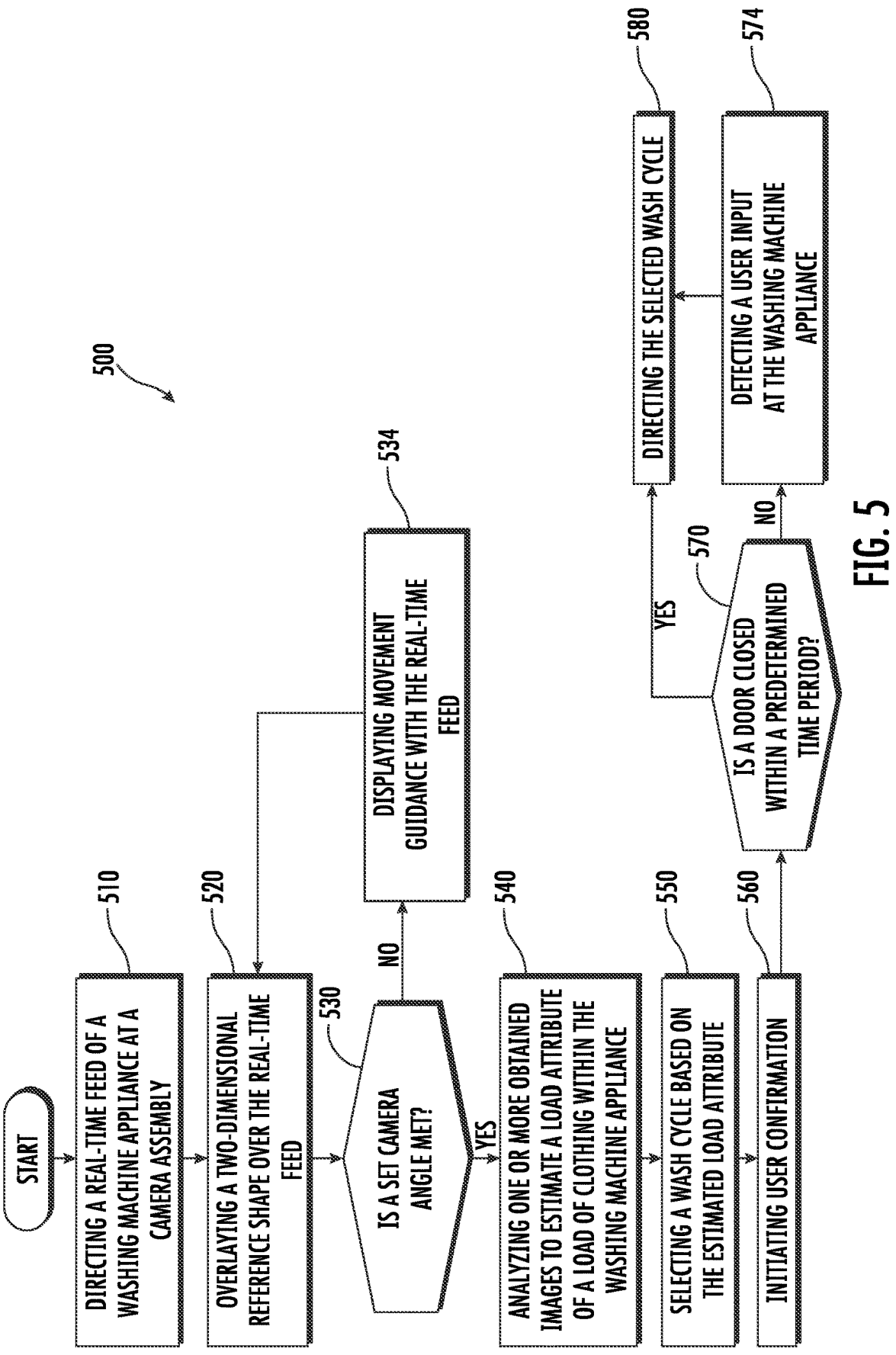
500
START
DIRECTING A REAL-TIME FEED OF A WASHING MACHINE APPLIANCE AT A CAMERA ASSEMBLY
510
OVERLAYING A TWO-DIMENSIONAL REFERENCE SHAPE OVER THE REAL-TIME FEED
520
IS A SET CAMERA ANGLE MET?
530
NO
DISPLAYING MOVEMENT GUIDANCE WITH THE REAL-TIME FEED
534
YES
ANALYZING ONE OR MORE OBTAINED IMAGES TO ESTIMATE A LOAD ATTRIBUTE OF A LOAD OF CLOTHING WITHIN THE WASHING MACHINE APPLIANCE
540
SELECTING A WASH CYCLE BASED ON THE ESTIMATED LOAD ATTRIBUTE
550
INITIATING USER CONFIRMATION
560
IS A DOOR CLOSED WITHIN A PREDETERMINED TIME PERIOD?
570
NO
DETECTING A USER INPUT AT THE WASHING MACHINE APPLIANCE
574
YES
DIRECTING THE SELECTED WASH CYCLE
580

FIG. 5

SYSTEMS AND METHODS USING IMAGE RECOGNITION PROCESSES AND DETERMINED DEVICE ORIENTATION FOR IMPROVED OPERATION OF A LAUNDRY APPLIANCE

FIELD OF THE INVENTION

The present subject matter relates generally to washing machine appliances, or more specifically, to systems and methods for using image recognition processes to improve or optimize operation of washing machine.

BACKGROUND OF THE INVENTION

Washing machine appliances generally include a tub for containing water or wash fluid, e.g., water and detergent, bleach, or other wash additives. A basket is rotatably mounted within the tub and defines a wash chamber for receipt of articles for washing. During normal operation of such washing machine appliances, the wash fluid is directed into the tub and onto articles within the wash chamber of the basket. The basket or an agitation element can rotate at various speeds to agitate articles within the wash chamber, to wring wash fluid from articles within the wash chamber, etc. During a spin or drain cycle, a drain pump assembly may operate to discharge water from within sump.

Notably, it is frequently desirable to understand characteristics of a load of clothes within the washing machine appliance, e.g., in order to optimize water usage, agitation time, agitation profile selection, and other wash parameters. For example, certain loads (e.g., towels or linens) may require more water and detergent, increased water temperature, and stronger agitation cycles. By contrast, other loads (e.g., such mixed color loads or delicates) may require cooler water and a gentler agitation profile. However, conventional washing machine appliances require a user to select operating cycles or specify the type of load added to the wash chamber, often resulting in inaccurate inputs or sub-optimal cycle settings. Attempts have been made to automatically (e.g., without direct user input or estimations) detect certain attributes of a load using sensors or detection assemblies within the washing machine appliance. Unfortunately, though, such systems may increase the expense and complexity of an appliance. Moreover, it can be difficult for a user to know if or when any detected attributes have been detected accurately or correctly.

Accordingly, a washing machine appliance with features for improved wash performance would be desirable. More specifically, a system and method for automatically detecting characteristics of the load of clothes and determining preferred operating parameters would be particularly beneficial, especially if such systems or methods could be achieved without requiring additional or dedicated sensing assemblies to be installed on the washing machine appliance. Additionally or alternatively, it may be beneficial to provide a system or method wherein a user could be confident that characteristics were detected in the correct manner (e.g., to ensure accuracy of such detections).

BRIEF DESCRIPTION OF THE INVENTION

Aspects and advantages of the invention will be set forth in part in the following description, or may be obvious from the description, or may be learned through practice of the invention.

In one exemplary aspect of the present disclosure, a method of operating a washing machine appliance is provided. The method may include obtaining one or more images of the washing machine appliance from a camera assembly of a remote device spaced apart from the cabinet. The method may also include receiving a plurality of angle readings from the remote device and determining a position of the remote device relative to the washing machine appliance based on the plurality of angle readings. The method may further include determining a set camera angle for the camera assembly is met based on the determined position of the remote device. The method may still further include analyzing at least one obtained image using a machine learning image recognition process, estimating a load attribute of a load of clothes within the washing machine appliance based on the analysis, and directing a wash cycle within the washing machine appliance based on the estimated load attribute.

In another exemplary aspect of the present disclosure, a method of operating a washing machine appliance is provided. The method may include obtaining one or more images of the washing machine appliance from a camera assembly of a remote device spaced apart from the cabinet. Obtaining one or more images may include receiving a video signal from the camera assembly. The method may also include presenting a real-time feed of the camera assembly at the remote device according to the received video signal and receiving a plurality of angle readings from the remote device. The method may further include determining a position of the remote device relative to the washing machine appliance based on the plurality of angle readings, overlaying a two-dimensional reference shape over the real-time feed, and determining a set camera angle for the camera assembly is met based on the determined position of the remote device. The method may still further include analyzing at least one obtained image using a machine learning image recognition process and estimating a load attribute of a load of clothes within the washing machine appliance based on the analysis. The load attribute may include at least one of a fabric type, a load color, or a load size. The method may yet further include directing a wash cycle within the washing machine appliance based on the estimated load attribute.

These and other features, aspects and advantages of the present invention will become better understood with reference to the following description and appended claims. The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

A full and enabling disclosure of the present invention, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the specification, which makes reference to the appended figures.

FIG. **1** provides a perspective view of an exemplary washing machine appliance according to an exemplary embodiment of the present subject matter.

FIG. **2** provides a side cross-sectional view of the exemplary washing machine appliance of FIG. **1**, along with a remote device movable relative to the washing machine appliance.

FIGS. **3**A, **3**B, **3**C, and **3**D provide illustrated plan views of a remote device displaying exemplary two dimensional images capturing a front portion of a washing machine

appliance having an open door according to exemplary embodiments of the present disclosure.

FIG. **4** provides a flow chart illustrating a method of operating a washing machine appliance according to exemplary embodiments of the present disclosure.

FIG. **5** provides a flow chart illustrating a method of operating a washing machine appliance according to exemplary embodiments of the present disclosure.

Repeat use of reference characters in the present specification and drawings is intended to represent the same or analogous features or elements of the present invention.

DETAILED DESCRIPTION

Reference now will be made in detail to embodiments of the invention, one or more examples of which are illustrated in the drawings. Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope of the invention. For instance, features illustrated or described as part of one embodiment can be used with another embodiment to yield a still further embodiment. Thus, it is intended that the present invention covers such modifications and variations as come within the scope of the appended claims and their equivalents.

As used herein, the terms "first," "second," and "third" may be used interchangeably to distinguish one component from another and are not intended to signify location or importance of the individual components. The terms "includes" and "including" are intended to be inclusive in a manner similar to the term "comprising." Similarly, the term "or" is generally intended to be inclusive (i.e., "A or B" is intended to mean "A or B or both"). In addition, here and throughout the specification and claims, range limitations may be combined or interchanged. Such ranges are identified and include all the sub-ranges contained therein unless context or language indicates otherwise. For example, all ranges disclosed herein are inclusive of the endpoints, and the endpoints are independently combinable with each other. The singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise.

Approximating language, as used herein throughout the specification and claims, may be applied to modify any quantitative representation that could permissibly vary without resulting in a change in the basic function to which it is related. Accordingly, a value modified by a term or terms, such as "generally," "about," "approximately," and "substantially," are not to be limited to the precise value specified. In at least some instances, the approximating language may correspond to the precision of an instrument for measuring the value, or the precision of the methods or machines for constructing or manufacturing the components or systems. For example, the approximating language may refer to being within a 10 percent margin, i.e., including values within ten percent greater or less than the stated value. In this regard, for example, when used in the context of an angle or direction, such terms include within ten degrees greater or less than the stated angle or direction, e.g., "generally vertical" includes forming an angle of up to ten degrees in any direction, e.g., clockwise or counterclockwise, with the vertical direction V.

The word "exemplary" is used herein to mean "serving as an example, instance, or illustration." In addition, references to "an embodiment" or "one embodiment" does not necessarily refer to the same embodiment, although it may. Any implementation described herein as "exemplary" or "an embodiment" is not necessarily to be construed as preferred or advantageous over other implementations. Moreover, each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope of the invention. For instance, features illustrated or described as part of one embodiment can be used with another embodiment to yield a still further embodiment. Thus, it is intended that the present invention covers such modifications and variations as come within the scope of the appended claims and their equivalents.

Referring now to the figures, an exemplary laundry appliance that may be used to implement aspects of the present subject matter will be described. Specifically, FIG. **1** is a perspective view of an exemplary horizontal axis washing machine appliance **100** and FIG. **2** is a side cross-sectional view of washing machine appliance **100**. As illustrated, washing machine appliance **100** generally defines a vertical direction V, a lateral direction L, and a transverse direction T, each of which is mutually perpendicular, such that an orthogonal coordinate system is generally defined.

According to exemplary embodiments, washing machine appliance **100** includes a cabinet **102** that is generally configured for containing or supporting various components of washing machine appliance **100** and which may also define one or more internal chambers or compartments of washing machine appliance **100**. In this regard, as used herein, the terms "cabinet," "housing," and the like are generally intended to refer to an outer frame or support structure for washing machine appliance **100**, e.g., including any suitable number, type, and configuration of support structures formed from any suitable materials, such as a system of elongated support members, a plurality of interconnected panels, or some combination thereof. It should be appreciated that cabinet **102** does not necessarily require an enclosure and may simply include open structure supporting various elements of washing machine appliance **100**. By contrast, cabinet **102** may enclose some or all portions of an interior of cabinet **102**. It should be appreciated that cabinet **102** may have any suitable size, shape, and configuration while remaining within the scope of the present subject matter.

As illustrated, cabinet **102** generally extends between a top **104** and a bottom **106** along the vertical direction V, between a first side **108** (e.g., the left side when viewed from the front as in FIG. **1**) and a second side **110** (e.g., the right side when viewed from the front as in FIG. **1**) along the lateral direction L, and between a front **112** and a rear **114** along the transverse direction T. In general, terms such as "left," "right," "front," "rear," "top," or "bottom" are used with reference to the perspective of a user accessing washing machine appliance **100**.

Referring to FIG. **2**, a wash basket **120** is rotatably mounted within cabinet **102** such that it is rotatable about an axis of rotation A. A motor **122**, e.g., such as a pancake motor, is in mechanical communication with wash basket **120** to selectively rotate wash basket **120** (e.g., during an agitation or a rinse cycle of washing machine appliance **100**). Wash basket **120** is received within a wash tub **124** and defines a wash chamber **126** that is configured for receipt of articles for washing. The wash tub **124** holds wash and rinse fluids for agitation in wash basket **120** within wash tub **124**. As used herein, "wash fluid" may refer to water, detergent, fabric softener, bleach, or any other suitable wash additive or combination thereof. Indeed, for simplicity of discussion,

these terms may all be used interchangeably herein without limiting the present subject matter to any particular "wash fluid."

Wash basket **120** may define one or more agitator features that extend into wash chamber **126** to assist in agitation and cleaning articles disposed within wash chamber **126** during operation of washing machine appliance **100**. For example, as illustrated in FIG. **2**, a plurality of ribs **128** extends from basket **120** into wash chamber **126**. In this manner, for example, ribs **128** may lift articles disposed in wash basket **120** during rotation of wash basket **120**.

According to exemplary embodiments, wash tub **124** may be generally suspended within cabinet **102** by one or more suspension assemblies **129**, e.g., as shown for example in FIG. **2**. In this regard, wash tub **124**, wash basket **120**, motor **122**, and other components of washing machine appliance **100** may be referred to generally herein as the subwasher. In order to reduce the transmission of vibrations and other forces from the subwasher to the cabinet **102** during operation of washing machine appliance **100**, wash tub **124** may be generally isolated from cabinet **102** by suspension assemblies **129**. This may be desirable to prevent undesirable noise, vibrations, "walking" of the appliance, etc. It should be appreciated that suspension assemblies **129** may generally include any suitable number and combination of springs, dampers, or other energy absorbing mechanisms to reduce the transmission of forces between the subwasher and cabinet **102**. Although exemplary suspensions assemblies **129** are illustrated herein, it should be appreciated that the number, type, and configuration of suspension assemblies **129** may vary while remaining within the scope of the present subject matter.

Referring generally to FIGS. **1** and **2**, cabinet **102** also includes a front panel **130** which defines an opening **132** that permits user access to wash basket **120** of wash tub **124**. More specifically, washing machine appliance **100** includes a door **134** that is positioned over opening **132** and is rotatably mounted to front panel **130**. In this manner, door **134** permits selective access to opening **132** by being movable between an open position (not shown) facilitating access to a wash tub **124** and a closed position (FIG. **1**) prohibiting access to wash tub **124**.

A window **136** in door **134** permits viewing of wash basket **120** when door **134** is in the closed position, e.g., during operation of washing machine appliance **100**. Door **134** also includes a handle (not shown) that, e.g., a user may pull when opening and closing door **134**. Further, although door **134** is illustrated as mounted to front panel **130**, it should be appreciated that door **134** may be mounted to another side of cabinet **102** or any other suitable support according to alternative embodiments. Washing machine appliance **100** may further include a latch assembly **138** (see FIG. **1**) that is mounted to cabinet **102** or door **134** for selectively locking door **134** in the closed position or confirming that the door is in the closed position. Latch assembly **138** may be desirable, for example, to ensure only secured access to wash chamber **126** or to otherwise ensure and verify that door **134** is closed during certain operating cycles or events.

Referring again to FIG. **2**, wash basket **120** also defines a plurality of perforations **140** in order to facilitate fluid communication between an interior of basket **120** and wash tub **124**. A sump **142** is defined by wash tub **124** at a bottom of wash tub **124** along the vertical direction V. Thus, sump **142** is configured for receipt of and generally collects wash fluid during operation of washing machine appliance **100**. For example, during operation of washing machine appliance **100**, wash fluid may be urged by gravity from basket **120** to sump **142** through plurality of perforations **140**.

A drain pump assembly **144** is located beneath wash tub **124** and is in fluid communication with sump **142** for periodically discharging soiled wash fluid from washing machine appliance **100**. Drain pump assembly **144** may generally include a drain pump **146** which is in fluid communication with sump **142** and with an external drain **148** through a drain hose **150**. During a drain cycle, drain pump **146** urges a flow of wash fluid from sump **142**, through drain hose **150**, and to external drain **148**. More specifically, drain pump **146** includes a motor (not shown) which is energized during a drain cycle such that drain pump **146** draws wash fluid from sump **142** and urges it through drain hose **150** to external drain **148**.

Washing machine appliance **100** may further include a wash fluid dispenser that is generally configured for dispensing a flow of water, wash fluid, etc. into wash tub **124**. For example, a spout **152** is configured for directing a flow of fluid into wash tub **124**. For example, spout **152** may be in fluid communication with a water supply **155** (FIG. **2**) in order to direct fluid (e.g., clean water or wash fluid) into wash tub **124**. Spout **152** may also be in fluid communication with the sump **142**. For example, pump assembly **144** may direct wash fluid disposed in sump **142** to spout **152** in order to circulate wash fluid in wash tub **124**.

As illustrated in FIG. **2**, a detergent drawer **156** is slidably mounted within front panel **130**. Detergent drawer **156** receives a wash additive (e.g., detergent, fabric softener, bleach, or any other suitable liquid or powder) and directs the fluid additive to wash tub **124** during operation of washing machine appliance **100**. According to the illustrated embodiment, detergent drawer **156** may also be fluidly coupled to spout **152** to facilitate the complete and accurate dispensing of wash additive. It should be appreciated that according to alternative embodiments, these wash additives could be dispensed automatically via a bulk dispensing unit (not shown). Other systems and methods for providing wash additives are possible and within the scope of the present subject matter.

In addition, a water supply valve **158** may provide a flow of water from a water supply source (such as a municipal water supply **155**) into detergent dispenser **156** and into wash tub **124**. In this manner, water supply valve **158** may generally be operable to supply water into detergent dispenser **156** to generate a wash fluid, e.g., for use in a wash cycle, or a flow of fresh water, e.g., for a rinse cycle. It should be appreciated that water supply valve **158** may be positioned at any other suitable location within cabinet **102**. In addition, although water supply valve **158** is described herein as regulating the flow of "wash fluid," it should be appreciated that this term includes, water, detergent, other additives, or some mixture thereof.

During operation of washing machine appliance **100**, laundry items are loaded into wash basket **120** through opening **132**, and washing operation is initiated through operator manipulation of one or more input selectors or using a remote device (see below). Wash tub **124** is filled with water, detergent, or other fluid additives, e.g., via spout **152** or detergent drawer **156**. One or more valves (e.g., water supply valve **158**) can be controlled by washing machine appliance **100** to provide for filling wash basket **120** to the appropriate level for the amount of articles being washed or rinsed. By way of example for a wash mode, once wash basket **120** is properly filled with fluid, the contents of wash basket **120** can be agitated (e.g., with ribs **128**) for washing of laundry items in wash basket **120**.

After the agitation phase of the wash cycle is completed, wash tub **124** can be drained. Laundry articles can then be rinsed by again adding fluid to wash tub **124**, depending on the particulars of the cleaning cycle selected by a user. Ribs **128** may again provide agitation within wash basket **120**. One or more spin cycles may also be used. In particular, a spin cycle may be applied after the wash cycle or after the rinse cycle in order to wring wash fluid from the articles being washed. During a final spin cycle, basket **120** is rotated at relatively high speeds and drain assembly **144** may discharge wash fluid from sump **142**. After articles disposed in wash basket **120** are cleaned, washed, or rinsed, the user can remove the articles from wash basket **120**, e.g., by opening door **134** and reaching into wash basket **120** through opening **132**.

Referring again to FIG. **1**, washing machine appliance **100** may include a control panel **160** that may represent a general-purpose Input/Output ("GPIO") device or functional block for washing machine appliance **100**. In some embodiments, control panel **160** may include or be in operative communication with one or more user input devices **162**, such as one or more of a variety of digital, analog, electrical, mechanical, or electro-mechanical input devices including rotary dials, control knobs, push buttons, toggle switches, selector switches, and touch pads. Additionally, washing machine appliance **100** may include a display **164**, such as a digital or analog display device generally configured to provide visual feedback regarding the operation of washing machine appliance **100**. For example, display **164** may be provided on control panel **160** and may include one or more status lights, screens, or visible indicators. According to exemplary embodiments, user input devices **162** and display **164** may be integrated into a single device, e.g., including one or more of a touchscreen interface, a capacitive touch panel, a liquid crystal display (LCD), a plasma display panel (PDP), a cathode ray tube (CRT) display, or other informational or interactive displays.

Washing machine appliance **100** may further include or be in operative communication with a processing device or a controller **166** that may be generally configured to facilitate appliance operation. In this regard, control panel **160**, user input devices **162**, and display **164** may be in communication with controller **166** such that controller **166** may receive control inputs from user input devices **162**, may display information using display **164**, and may otherwise regulate operation of washing machine appliance **100**. For example, signals generated by controller **166** may operate washing machine appliance **100**, including any or all system components, subsystems, or interconnected devices, in response to the position of user input devices **162** and other control commands. Control panel **160** and other components of washing machine appliance **100** may be in communication with controller **166** via, for example, one or more signal lines or shared communication busses. In this manner, Input/Output ("I/O") signals may be routed between controller **166** and various operational components of washing machine appliance **100**.

As used herein, the terms "processing device," "computing device," "controller," or the like may generally refer to any suitable processing device, such as a general or special purpose microprocessor, a microcontroller, an integrated circuit, an application specific integrated circuit (ASIC), a digital signal processor (DSP), a field-programmable gate array (FPGA), a logic device, one or more central processing units (CPUs), a graphics processing units (GPUs), processing units performing other specialized calculations, semiconductor devices, etc. In addition, these "controllers" are not necessarily restricted to a single element but may include any suitable number, type, and configuration of processing devices integrated in any suitable manner to facilitate appliance operation. Alternatively, controller **166** may be constructed without using a microprocessor, e.g., using a combination of discrete analog or digital logic circuitry (such as switches, amplifiers, integrators, comparators, flip-flops, OR gates, and the like) to perform control functionality instead of relying upon software.

Controller **166** may include, or be associated with, one or more memory elements or non-transitory computer-readable storage mediums, such as RAM, ROM, EEPROM, EPROM, flash memory devices, magnetic disks, or other suitable memory devices (including combinations thereof). These memory devices may be a separate component from the processor or may be included onboard within the processor. In addition, these memory devices can store information or data accessible by the one or more processors, including instructions that can be executed by the one or more processors. It should be appreciated that the instructions can be software written in any suitable programming language or can be implemented in hardware. Additionally, or alternatively, the instructions can be executed logically or virtually using separate threads on one or more processors.

For example, controller **166** may be operable to execute programming instructions or micro-control code associated with an operating cycle of washing machine appliance **100**. In this regard, the instructions may be software or any set of instructions that when executed by the processing device, cause the processing device to perform operations, such as running one or more software applications, displaying a user interface, receiving user input, processing user input, etc. Moreover, it should be noted that controller **166** as disclosed herein is capable of and may be operable to perform any methods, method steps, or portions of methods of appliance operation. For example, in some embodiments, these methods may be embodied in programming instructions stored in the memory and executed by controller **166**.

The memory devices may also store data that can be retrieved, manipulated, created, or stored by the one or more processors or portions of controller **166**. The data can include, for instance, data to facilitate performance of methods described herein. The data can be stored locally (e.g., on controller **166**) in one or more databases or may be split up so that the data is stored in multiple locations. In addition, or alternatively, the one or more database(s) can be connected to controller **166** through any suitable network(s), such as through a high bandwidth local area network (LAN) or wide area network (WAN). In this regard, for example, controller **166** may further include a communication module or interface that may be used to communicate with one or more other component(s) of washing machine appliance **100**, controller **166**, an external device **182** (e.g., device controller **188**), or any other suitable device, e.g., via any suitable communication lines or network(s) and using any suitable communication protocol. The communication interface can include any suitable components for interfacing with one or more network(s), including for example, transmitters, receivers, ports, controllers, antennas, or other suitable components.

Referring again to FIG. **1**, a schematic diagram of an external communication system **180** will be described according to an exemplary embodiment of the present subject matter. In general, external communication system **180** is configured for permitting interaction, data transfer, and other communications between washing machine appliance **100** and one or more remote external devices. For

example, this communication may be used to provide and receive operating parameters, user instructions or notifications, performance characteristics, user preferences, or any other suitable information for improved performance of washing machine appliance **100**. In addition, it should be appreciated that external communication system **180** may be used to transfer data or other information to improve performance of one or more external devices or appliances or improve user interaction with such devices.

For example, external communication system **180** permits controller **166** of washing machine appliance **100** to communicate with a separate device external to washing machine appliance **100**, referred to generally herein as a remote or external device **182**. As described in more detail below, these communications may be facilitated using a wired or wireless connection, such as via a network **184**. In general, external device **182** may be any suitable device separate from washing machine appliance **100** that is configured to provide or receive communications, information, data, or commands from a user. In this regard, external device **182** may be, for example, a personal phone, a smartphone, a tablet, a laptop or personal computer, a wearable device, a smart home system, or another mobile or remote device. In turn, external device **182** may include a monitor or screen **190** configured to display digital two-dimensional images, as would be understood.

In some embodiments, remote user device **182** includes a camera or camera module **178**. Camera **178** may be any type of device suitable for capturing a two-dimensional picture or image. As an example, camera **178** may be a video camera or a digital camera with an electronic image sensor [e.g., a charge coupled device (CCD) or a CMOS sensor]. When assembled, camera **178** is generally mounted or fixed to a body of remote user device **182** and is in communication (e.g., electric or wireless communication) with a controller **188** of the remote user device **182** such that the controller may receive a signal from camera **178** corresponding to the image captured by camera **178**.

Generally, external device **182** may include a controller **188** (e.g., including one or more suitable processing devices, such as a general or special purpose microprocessor, a microcontroller, an integrated circuit, an application specific integrated circuit (ASIC), a digital signal processor (DSP), a field-programmable gate array (FPGA), a logic device, one or more central processing units (CPUs), a graphics processing units (GPUs), processing units performing other specialized calculations, semiconductor devices, etc. Controller **188** may include, or be associated with, one or more memory elements or non-transitory computer-readable storage mediums, such as RAM, ROM, EEPROM, EPROM, flash memory devices, magnetic disks, or other suitable memory devices (including combinations thereof). These memory devices may be a separate component from the processor of controller **188** or may be included onboard within such processor. In addition, these memory devices can store information or data accessible by the one or more processors of the controller **188**, including instructions that can be executed by the one or more processors. It should be appreciated that the instructions can be software written in any suitable programming language or can be implemented in hardware. Additionally, or alternatively, the instructions can be executed logically or virtually using separate threads on one or more processors.

For example, controller **188** may be operable to execute programming instructions or micro-control code associated with operation of or engagement with washing machine appliance **100**. In this regard, the instructions may be software or any set of instructions that when executed by the processing device, cause the processing device to perform operations, such as running one or more software applications, displaying or directing a user interface, receiving user input, processing user input, etc. Moreover, it should be noted that controller **188** as disclosed herein is capable of and may be operable to perform one or more methods, method steps, or portions of methods of appliance operation. For example, in some embodiments, these methods may be embodied in programming instructions stored in the memory and executed by controller **188**.

The memory devices of controller **188** may also store data that can be retrieved, manipulated, created, or stored by the one or more processors or portions of controller **166**. The data can include, for instance, data to facilitate performance of methods described herein. store data that can be retrieved, manipulated, created, or stored by the one or more processors or portions of controller **188**. The data can include, for instance, data to facilitate performance of methods described herein. As an example, and turning briefly to FIGS. **3**A, **3**B, **3**C, and **3**D, the data may include identifying information to identify or detect a fiducial reference **210** on a front portion of the washing machine appliance **100** (e.g., using camera **178**). In some embodiments, controller **188** may be configured to direct a presentation or display of a real-time feed from the camera **178** (e.g., on monitor **190**). Optionally, a two-dimensional reference shape **212** for alignment of the external device **182** may be displayed. Moreover, movement guidance **214** (e.g., in the form of pictorial or textual instructions, such as arrows or written messages) may be displayed such that a user can properly align the camera **178** to capture an image that may be further analyzed (e.g., to estimate one or more load attributes of a load of clothes **172** within the wash chamber **126**).

In certain embodiments, a measurement device **192** may be included with or connected to controller **188** on external device **182**. Moreover, measurement devices **192** may include a microprocessor that performs the calculations specific to the measurement of position or movement with the calculation results being used by controller **188**. Generally, measurement device **192** may detect a plurality of angle readings. For instance, multiple angle readings may be detected simultaneously to track multiple (e.g., mutually orthogonal) axes of the external device **182**, such as an X-axis, Y-axis, and Z-axis shown in FIG. **2**. For instance, the axes may be detected or tracked relative to gravity and, thus, the installed washing machine appliance **100**. Optionally, a measurement device **192** may be or include an accelerometer, which measures, at least in part, the effects of gravity (e.g., as an acceleration component), such as acceleration along one or more predetermined directions. Additionally or alternatively, a measurement device **192** may be or include a gyroscope, which measures rotational positioning (e.g., as a rotation component).

A measurement device **192** in accordance with the present disclosure can be mounted on or within the external device **182**, as required to sense movement or position of external device **182** relative to the cabinet **102** of appliance **100**. Optionally, measurement device **192** may include at least one gyroscope or at least one accelerometer. The measurement device **192**, for example, may be a printed circuit board which includes the gyroscope and accelerometer thereon.

Returning generally to FIG. **1**, the data of controller **188** can be stored locally (e.g., on controller **188**) in one or more databases or may be split up so that the data is stored in multiple locations. In addition, or alternatively, the one or more database(s) can be connected to controller **188** through

any suitable network(s), such as through a high bandwidth local area network (LAN) or wide area network (WAN). In this regard, for example, controller **188** may further include a communication module or interface that may be used to communicate with washing machine appliance **100**, controller **166**, or any other suitable device, e.g., via any suitable communication lines or network(s) and using any suitable communication protocol. The communication interface can include any suitable components for interfacing with one or more network(s), including for example, transmitters, receivers, ports, controllers, antennas, or other suitable components.

Separate from or in addition to external device **182**, a remote server **186** may be in communication with washing machine appliance **100** or external device **182** through network **184**. In this regard, for example, remote server **186** may be a cloud-based server **186**, and is thus located at a distant location, such as in a separate state, country, etc. According to an exemplary embodiment, external device **182** may communicate with a remote server **186** over network **184**, such as the Internet, to transmit/receive data or information, provide user inputs, receive user notifications or instructions, interact with or control washing machine appliance **100**, etc. In addition, external device **182** and remote server **186** may communicate with washing machine appliance **100** to communicate similar information.

In general, communication between washing machine appliance **100**, external device **182**, remote server **186**, or other user devices or appliances may be carried using any type of wired or wireless connection and using any suitable type of communication network, non-limiting examples of which are provided below. For example, external device **182** may be in direct or indirect communication with washing machine appliance **100** through any suitable wired or wireless communication connections or interfaces, such as network **184**. For example, network **184** may include one or more of a local area network (LAN), a wide area network (WAN), a personal area network (PAN), the Internet, a cellular network, any other suitable short- or long-range wireless networks, etc. In addition, communications may be transmitted using any suitable communications devices or protocols, such as via Wi-Fi®, Bluetooth®, Zigbee®, wireless radio, laser, infrared, Ethernet type devices and interfaces, etc. In addition, such communication may use a variety of communication protocols (e.g., TCP/IP, HTTP, SMTP, FTP), encodings or formats (e.g., HTML, XML), or protection schemes (e.g., VPN, secure HTTP, SSL).

External communication system **180** is described herein according to an exemplary embodiment of the present subject matter. However, it should be appreciated that the exemplary functions and configurations of external communication system **180** provided herein are used only as examples to facilitate description of aspects of the present subject matter. System configurations may vary, other communication devices may be used to communicate directly or indirectly with one or more associated appliances, other communication protocols and steps may be implemented, etc. These variations and modifications are contemplated as within the scope of the present subject matter.

Now that the construction of washing machine appliance **100** and the configuration of controller **188** according to exemplary embodiments have been presented, exemplary methods (e.g., methods **400** and **500**) of operating a washing machine appliance will be described. Although the discussion below refers to the exemplary methods **400** and **500** of operating washing machine appliance **100**, one skilled in the art will appreciate that the exemplary methods **400** and **500** are applicable to the operation of a variety of other washing machine appliances, such as vertical axis washing machine appliances. In exemplary embodiments, the various method steps as disclosed herein may be performed (e.g., in whole or part) by controller **188**, controller **166**, or another, separate, dedicated controller.

FIGS. **4** and **5** depict steps performed in a particular order for purpose of illustration and discussion. Those of ordinary skill in the art, using the disclosures provided herein, will understand that (except as otherwise indicated) methods **400** and **500** are not mutually exclusive. Moreover, the steps of the methods **400** and **500** can be modified, adapted, rearranged, omitted, interchanged, or expanded in various ways without deviating from the scope of the present disclosure.

Advantageously, methods in accordance with the present disclosure may permit one or more attributes of a load of clothes to be automatically and accurately determined. Additionally or alternatively, a user may be advantageously guided to ensure consistent and accurate images are gathered to, in turn, ensure accuracy of any further determinations.

Referring now to FIG. **4**, at **410**, the method **400** includes obtaining one or more images of the washing machine appliance from a camera assembly or module of a remote device (i.e., external device). In particular, the camera of the external device may be aimed at the washing machine appliance. Along with the cabinet or basket of the washing machine appliance, such images may include a load of clothes that are to be washed during a wash cycle of a washing machine appliance. In this regard, continuing the example from above, load of clothes may be placed within wash chamber of the washing machine appliance prior to closing the door and implementing a wash cycle.

It should be appreciated that obtaining the images may include obtaining more than one image, a series of frames, a video, or any other suitable visual representation of the load of clothes using the camera assembly. Thus, **410** may include receiving a video signal from the camera assembly. Separate from or in addition to the video signal, the images obtained by the camera assembly may vary in number, frequency, angle, resolution, detail, etc. in order to improve the clarity of the load of clothes. In addition, the obtained images may also be cropped in any suitable manner for improved focus on desired portions of the load of clothes.

In optional embodiments, the obtained images can be presented or displayed as a real-time feed of the camera assembly at the remote device (e.g., according to the received video signal). For instant, a constant or regularly refreshing set of live images from the camera assembly may be presented on the monitor or screen of the remote device. Thus, a user viewing the remote device may be able to see the field of view being captured by the camera assembly (e.g., without having to repeatedly freeze the frame or provide any active input by a user on the remote device).

The one or more images may be obtained using the camera assembly at any suitable time prior to initiating the wash cycle. For example, as best illustrated in FIGS. **3**A through **3**D, these images may be obtained when the door is in the open position (e.g., such that the field of view of the camera can capture at least a portion of the wash chamber through the front opening).

In certain embodiments, detection of the obtaining the images may permit or prompt determination that the door of the washing machine appliance is open. For instance, the method **400** may include determining the door is open based on one or more of the obtained images. Additionally or alternatively, determining the door is open may be based on

a separate signal (e.g., received from the latch assembly) physically detecting a position of the door.

Following or in tandem with **410**, the method **400** may proceed to either one or both of **420**A and **420**B. In turn, the method **400** may execute either **420**A, **420**B, or both **420**A and **420**B before proceeding to **430**A or **430**B, respectively.

At **420**A, the method **400** includes receiving a plurality of angle readings from the remote device. Such angle readings may generally indicate the position of the remote device (e.g., in multiple dimensions, such as three) relative to a fixed direction, axis, or point. For instance, the multiple readings may be detected for the remote device relative to gravity. The angle readings may be received following or in tandem with **410**. In some embodiments, the angle readings may be received from a measurement device of the remote device (e.g., as described above). In particular, the measurement device may include an accelerometer configured to detect the tilt or angle of the remote device, as would be understood.

In certain embodiments, detection of the fiducial reference may permit or prompt determination that the door of the washing machine appliance is open. Thus, the method **400** may include determining the door is open based on one or more of the obtained images. Additionally or alternatively, determining the door is open may be based on a separate signal (e.g., received from the latch assembly) physically detecting a position of the door.

At **430**A, the method **400** includes determining a position (e.g., tilt or angular position) of the remote device relative to the washing machine appliance. In particular, the determination of the position may be based on the angle readings from **420**A. For instance, the angle readings may indicate how the remote device (and thus camera assembly) is oriented in space. As the washing machine appliance is generally stationary, the position of the remote device relative to the washing machine appliance may further be determined, as would be understood in light of the present disclosure.

Returning now to **420**B, at **420**B, the method **400** includes detecting a fiducial reference on a front portion of the washing machine appliance within the one or more images. For instance, from the obtained images, the controller may identify the region corresponding to a predetermined portion of the washing machine appliance, which serves as the fiducial reference. Any suitable portion at the front of the washing machine appliance may serve as the fiducial marker. In some embodiments, the fiducial reference is the front opening (e.g., as defined by the cabinet, wash basket, or a gasket extending between the two) permitting access to the wash chamber (e.g., as indicated in FIGS. **3**A through **3**D).

As is understood, recognizing or identifying such fiducial references or portions of the appliance, may be performed by one or more image processing techniques or algorithms (e.g., executed at the controller of the remote device, remote server, or appliance). According to exemplary embodiments, image processing may include blur detection algorithms that are generally intended to compute, measure, or otherwise determine the amount of blur in an image. For example, these blur detection algorithms may rely on focus measure operators, the Fast Fourier Transform along with examination of the frequency distributions, determining the variance of a Laplacian operator, or any other methods of blur detection known by those having ordinary skill in the art. In addition, or alternatively, the image processing algorithms may use other suitable techniques for recognizing or identifying items or objects, such as edge matching or detection, divide-and-conquer searching, greyscale matching, histograms of receptive field responses, or another suitable routine (e.g., executed at the controller of the remote device, remote server, or appliance based on one or more captured images from one or more cameras). Other image processing techniques are possible and within the scope of the present subject matter. The processing algorithm may further include measures for isolating or eliminating noise in the image comparison, e.g., due to image resolution, data transmission errors, inconsistent lighting, or other imaging errors. By eliminating such noise, the image processing algorithms may improve accurate object detection, avoid erroneous object detection, and isolate the important object, region, or pattern within an image.

At **430**B, the method **400** includes comparing the detected fiducial reference to a two-dimensional reference shape in an obtained image of the one or more images. As would be understood, the two-dimensional geometry of a fiducial reference captured in an obtained image will vary depending on the angle of the camera when the image is obtained. The two-dimensional reference shape may correspond to the geometry of the fiducial reference in a set or predetermined camera angle (e.g., in which images to accurately analyze the load within the wash chamber may be obtained). As an example, the two-dimensional reference shape may be a circle, such as may correspond to an intended geometry of the opening in a set angle of the camera. From the comparison, it may be determined if the fiducial reference matches the two-dimensional reference shape (e.g., the fiducial reference within the obtained image has dimensions that are within a set tolerance or range of the two-dimensional reference shape, such as 10%). For instance, the size or eccentricity of the fiducial reference within the obtained image may be calculated and compared to the size or eccentricity programmed for the two-dimensional reference shape.

In certain embodiments, the two-dimensional reference shape may be overlaid on the real-time feed (e.g., presented on the remote device). Thus, as would be understood, a representation of the two-dimensional reference shape may be overlaid onto the real-time feed of the camera and appears as a fixed object in front of the digital representation (i.e., video) of the washing machine appliance on the monitor of the remote device. The position of the two-dimensional reference shape that is displayed or overlaid may be constant, even as the camera angle and obtained images change. Thus, a user may be guided to move the camera such that the fiducial reference aligns to (e.g., behind) the overlaid two-dimensional reference shape. Separate from or in addition to the two-dimensional reference shape, the method **400** may provide for displaying movement guidance (e.g., in the form of pictorial or textual instructions, such as arrows or written messages) with the real-time feed (e.g., to help a user move the camera to align the two-dimensional reference shape with the fiducial reference).

At **440**, the method **400** includes determining a set camera angle for the camera assembly is met (e.g., based on **430**A or **430**B). As an example, the determined position of the remote device may be determined to match the set camera angle (e.g., within a set tolerance or range, such as 10%). As an additional or alternative example, it may be determined that, within an obtained image, the fiducial reference matches or is aligned with the two-dimensional reference shape. Specifically, it may be determined that the fiducial reference in the obtained image has dimensions that corre-

spond in size, curve, or location (e.g., within a set tolerance or range, such as 10%) to the dimensions of the two-dimensional reference shape.

In optional embodiments, a feedback signal is generated (e.g., at the remote device) in response to **440**. Such a feedback signal may prompt a feedback action (e.g., visual alert on the monitor, haptic movement at the remote appliance, audio tone, etc.) corresponding to the set camera angle being met such that a user can know further movement of the camera is unnecessary.

At **450**, the method **400** includes analyzing the obtained image using a machine learning image recognition process to estimate a load attribute of a load of clothes within the washing machine appliance based on the analysis. As used herein, the term "load attribute" and the like is intended to refer to any qualitative or quantitative characteristic of clothes within the wash chamber. For example, the load attribute may refer to a fabric type, a load color (such as white, light, dark, or mixed), or a load size (e.g., volume, mass, weight, etc.). In addition, it should be appreciated that the load attribute may be an approximation or best fit representation of a load of clothes. For example, a controller may be programmed with thresholds for determining whether a load qualifies as a white load, such as greater than 70% whites, greater than 80% whites, greater than 90% whites, greater than 95% whites, etc.).

In addition to providing approximations regarding primary load attributes such as type of fabric, color, and size, **450** may further include extracting information regarding outliers relative to the average load attribute. For example, if a load is detected as being primarily white or light colors, an outlier may be a single dark garment within the load (e.g., such as a red sock within a load of whites). In addition, **450** may include extracting or identifying unwashable items, such as a belt, a wallet, or another item which was likely inadvertently added into the wash chamber. In sum, **450** may be used for determining any suitable load attribute or other feature of a load of clothes that may be useful in adjusting the operation of washing machine appliance to achieve a better outcome, such as improved efficiency, improved wash performance, etc.

As used herein, the terms image recognition, object detection, and similar terms may be used generally to refer to any suitable method of observation, analysis, image decomposition, feature extraction, image classification, etc. of one or more image or videos taken within a wash chamber of a washing machine appliance. It should be appreciated that any suitable image recognition software or process may be used to analyze images taken by the camera assembly and a controller may be programmed to perform such processes and take corrective action.

In certain embodiments, the image analysis may include utilizing artificial intelligence ("AI"), such as a machine learning image recognition process, a neural network classification module, any other suitable artificial intelligence (AI) technique, or any other suitable image analysis techniques, examples of which will be described in more detail below. Moreover, each of the exemplary image analysis or evaluation processes described below may be used independently, collectively, or interchangeably to extract detailed information regarding the images being analyzed to facilitate performance of one or more methods described herein or to otherwise improve appliance operation. According to exemplary embodiments, any suitable number and combination of image processing, image recognition, or other image analysis techniques may be used to obtain an accurate analysis of the obtained images.

In this regard, the image recognition process may use any suitable artificial intelligence technique, for example, any suitable machine learning technique, or for example, any suitable deep learning technique. According to an exemplary embodiment, controller may implement a form of image recognition called region based convolutional neural network ("R-CNN") image recognition. Generally speaking, R-CNN may include taking an input image and extracting region proposals that include a potential object, such as an item of clothing (e.g., jeans, socks, etc.) or an undesirable article (e.g., a belt, a wallet, etc.). In this regard, a "region proposal" may be regions in an image that could belong to a particular object. A convolutional neural network is then used to compute features from the regions proposals and the extracted features will then be used to determine a classification for each particular region.

According to still other embodiments, an image segmentation process may be used along with the R-CNN image recognition. In general, image segmentation creates a pixel-based mask for each object in an image and provides a more detailed or granular understanding of the various objects within a given image. In this regard, instead of processing an entire image—i.e., a large collection of pixels, many of which might not contain useful information-image segmentation may involve dividing an image into segments (e.g., into groups of pixels containing similar attributes) that may be analyzed independently or in parallel to obtain a more detailed representation of the object or objects in an image. This may be referred to herein as "mask R-CNN" and the like. It should be appreciated that any other suitable image recognition process may be used while remaining within the scope of the present subject matter.

According to still other embodiments, the image recognition process may use any other suitable neural network process. For example, 450 may include using Mask R-CNN instead of a regular R-CNN architecture. In this regard, Mask R-CNN is based on Fast R-CNN which is slightly different than R-CNN. For example, R-CNN first applies CNN and then allocates it to zone recommendations on the covn5 property map instead of the initially split into zone recommendations. In addition, according to exemplary embodiments standard CNN may be used to analyze the image and estimate load size or main load fabric type of the load within the wash basket. In addition, a K-means algorithm may be used for dominant color analysis to find individual color of fabrics to serve with warnings.

According to exemplary embodiments the image recognition process may further include the implementation of Vision Transformer (ViT) techniques or models. In this regard, ViT is generally intended to refer to the use of a vision model based on the Transformer architecture originally designed and commonly used for natural language processing or other text-based tasks. For example, ViT represents an input image as a sequence of image patches and directly predicts class labels for the image. This process may be similar to the sequence of word embeddings used when applying the Transformer architecture to text. The ViT model and other image recognition models described herein may be trained using any suitable source of image data in any suitable quantity. Notably, ViT techniques have been demonstrated to outperform many state-of-the-art neural network or artificial intelligence image recognition processes.

According to still other embodiments, the image recognition process may use any other suitable neural network process while remaining within the scope of the present subject matter. For example, the step of analyzing the one or

more images may include using a deep belief network ("DBN") image recognition process. A DBN image recognition process may generally include stacking many individual unsupervised networks that use each network's hidden layer as the input for the next layer. According to still other embodiments, the step of analyzing one or more images may include the implementation of a deep neural network ("DNN") image recognition process, which generally includes the use of a neural network (computing systems inspired by the biological neural networks) with multiple layers between input and output. Other suitable image recognition processes, neural network processes, artificial intelligence analysis techniques, and combinations of the above described or other known methods may be used while remaining within the scope of the present subject matter.

In addition, it should be appreciated that various transfer techniques may be used but use of such techniques is not required. If using transfer techniques learning, a neural network architecture may be pretrained such as VGG16/VGG19/ResNet50 with a public dataset then the last layer may be retrained with an appliance specific dataset. In addition, or alternatively, the image recognition process may include detection of certain conditions based on comparison of initial conditions, may rely on image subtraction techniques, image stacking techniques, image concatenation, etc. For example, the subtracted image may be used to train a neural network with multiple classes for future comparison and image classification.

It should be appreciated that the machine learning image recognition models may be actively trained by the appliance with new images, may be supplied with training data from the manufacturer or from another remote source, or may be trained in any other suitable manner. For example, according to exemplary embodiments, this image recognition process relies at least in part on a neural network trained with a plurality of images of the appliance in different configurations, experiencing different conditions, or being interacted with in different manners. This training data may be stored locally or remotely and may be communicated to a remote server for training other appliances and models. According to exemplary embodiments, it should be appreciated that the machine learning models may include supervised or unsupervised models and methods. In this regard, for example, supervised machine learning methods (e.g., such as targeted machine learning) may help identify problems, anomalies, or other occurrences which have been identified and trained into the model. By contrast, unsupervised machine learning methods may be used to detect clusters of potential failures, similarities among data, event patterns, abnormal concentrations of a phenomenon, etc.

It should be appreciated that image processing and machine learning image recognition processes may be used together to facilitate improved image analysis, object detection, color detection, or to extract other useful qualitative or quantitative data or information from the one or more images that may be used to improve the operation or performance of the appliance. Indeed, the methods described herein may use any or all of these techniques interchangeably to improve image analysis process and facilitate improved appliance performance and consumer satisfaction. The image processing algorithms and machine learning image recognition processes described herein are only exemplary and are not intended to limit the scope of the present subject matter in any manner.

At **460**, the method **400** includes directing a wash cycle within the washing machine appliance based on the estimated load attribute (e.g., from **450**). Such direction may require adjusting one or more operating parameters of the washing machine appliance (e.g., as part of the wash cycle, which may then be initiated). Thus, **460** may include selecting an operating cycle parameter, adjusting a water or detergent fill amount, or providing a user notification. As used herein, an "operating parameter" of the washing machine appliance is any cycle setting, operating time, component setting, spin speed, part configuration, or other operating characteristic that may affect the performance of the washing machine appliance. In turn, references to operating parameter adjustments or "adjusting at least one operating parameter" are intended to refer to control actions intended to improve system performance based on the load characteristics. For example, adjusting an operating parameter may include adjusting an agitation time or an agitation profile, adjusting a water level, limiting a spin speed of the wash basket, etc. Other operating parameter adjustments are possible and within the scope of the present subject matter.

For example, according to an exemplary embodiment, the mask R-CNN image recognition process may be used on one or more images obtained at **410** to determine that the load of clothes is primarily delicate garments. As a result, it may further be determined that cool water should be used (e.g., below a certain temperature), that the agitation profile should be gentle, and that the total wash time should be decreased. One or more of the corresponding controllers may automatically detect and implement such a wash cycle without requiring user input. By contrast, if a load of sheets or towels is detected, a large volume of hot water may be used with more detergent and an aggressive agitation profile. It should be appreciated that the exemplary load characteristics and the exemplary operating parameters described herein are only exemplary and not intended to limit the scope of the present subject matter in any manner.

In addition, adjusting the at least one operating parameter may include providing a user notification when a predetermined load attribute exists. For example, if **450** results in the detection of an unwashable item, the wash cycle may be restricted (e.g., stopped or otherwise prevented) and a user notification may be provided, e.g., via an indicator on the remote device or the control panel of the appliance. Thus, for example, if a user inadvertently leaves their belt in a pair of pants thrown into the wash chamber, images obtained by the camera assembly may be used to detect the belt and instruct the user to remove the belt before the wash cycle commences. Similarly, if **450** detects a single light item in a load of dark clothes or a single dark item in a load of light clothes, a user may be notified of such condition or the wash cycle may be adjusted to reduce the temperature of water added during a wash cycle to reduce the likelihood of bleeding between the different color articles. According to another exemplary embodiment, the unwashable item may be a child, a pet, or any other item that is not intended for washing or drying. It should be appreciated that the items identified herein as "unwashable" are only exemplary and are not intended to limit the scope of the present subject matter.

In some embodiments, the start of the wash cycle at **460** may be contingent on one or more predetermined conditions. As an example, it may be required that a door shuts within a predetermined time period (e.g., less than one minute, such as a period less than or equal to 30 seconds, 15 seconds, or 5 seconds) following **410** or **440** (e.g., measured in response to **410** or **440**). For instance, the method **400** may include determining the door of the washing machine appliance is closed within the predetermined time period (e.g., following **410**). Such as determination may be based

on a signal from the latch assembly or a subsequently received image from the camera assembly. In turn, **460** may be in response to determining the door is closed within the predetermined time period. If the door is not determined to close within the predetermined time period (e.g., determination of the door being closed within the predetermined time period fails), a user may be required to manually input a start signal (e.g., by pressing a button) at the control panel of the washing machine appliance in order to prompt **460**.

Turning now to FIG. **5**, at **510**, the method **500** includes directing a real-time video feed of a washing machine appliance (e.g., a front portion or wash chamber of the same) at a camera assembly of a remote device. Thus, **510** includes obtaining more than one image, a series of frames, a video, or any other suitable visual representation of the washing machine appliance (and clothes therein) from the camera assembly or module of a remote device (i.e., external device), such as described above. In turn, **510** may include receiving a video signal from the camera assembly. Separate from or in addition to the video signal, the images obtained by the camera assembly may vary in number, frequency, angle, resolution, detail, etc. in order to improve the clarity of the load of clothes. In addition, the obtained images may also be cropped in any suitable manner for improved focus on desired portions of the load of clothes.

The obtained images are then presented or displayed as a real-time feed of the camera assembly at the remote device (e.g., according to the received video signal). For instant, a constant or regularly refreshing set of live images from the camera assembly may be presented on the monitor or display of the remote device. Thus, a user viewing the remote device may be able to see the field of view being captured by the camera assembly (e.g., without having to repeatedly freeze the frame or provide any active input by a user on the remote device).

The images may be obtained using the camera assembly at any suitable time prior to initiating the wash cycle. For example, as best illustrated in FIGS. **3**A through **3**D, these images may be obtained when the door is in the open position (e.g., such that the field of view of the camera can capture at least a portion of the wash chamber through the front opening).

In some embodiments, **510** includes detecting a fiducial reference on a front portion of the washing machine appliance within the images of the real-time video feed. For instance, from the obtained images, the controller may identify the region corresponding to a predetermined portion of the washing machine appliance, which serves as the fiducial reference. Any suitable portion at the front of the washing machine appliance may serve as the fiducial marker. In some embodiments, the fiducial reference is the front opening (e.g., as defined by the cabinet, wash basket, or a gasket extending between the two) permitting access to the wash chamber (e.g., as indicated in FIGS. **3**A through **3**D).

As is understood, recognizing or identifying such fiducial references or portions of the appliance, may be performed by one or more image processing techniques or algorithms (e.g., executed at the controller of the remote device, remote server, or appliance). According to exemplary embodiments, image processing may include blur detection algorithms that are generally intended to compute, measure, or otherwise determine the amount of blur in an image. For example, these blur detection algorithms may rely on focus measure operators, the Fast Fourier Transform along with examination of the frequency distributions, determining the variance of a Laplacian operator, or any other methods of blur detection known by those having ordinary skill in the art. In addition, or alternatively, the image processing algorithms may use other suitable techniques for recognizing or identifying items or objects, such as edge matching or detection, divide-and-conquer searching, greyscale matching, histograms of receptive field responses, or another suitable routine (e.g., executed at the controller of the remote device, remote server, or appliance based on one or more captured images from one or more cameras). Other image processing techniques are possible and within the scope of the present subject matter. The processing algorithm may further include measures for isolating or eliminating noise in the image comparison, e.g., due to image resolution, data transmission errors, inconsistent lighting, or other imaging errors. By eliminating such noise, the image processing algorithms may improve accurate object detection, avoid erroneous object detection, and isolate the important object, region, or pattern within an image.

At **520**, the method **500** includes overlaying a two-dimensional reference shape over the real-time video feed. The two-dimensional reference shape may generally correspond to the geometry of a portion of the washing machine appliance to which the camera assembly or field of view is intended to be aligned (e.g., the fiducial reference). As an example, the two-dimensional reference shape may be a circle, such as may correspond to an intended geometry of the opening in a set angle of the camera.

Generally, a representation of the two-dimensional reference shape is overlaid onto the real-time feed of the camera and appears as a fixed object in front of the digital representation (i.e., video) of the washing machine appliance on the monitor of the remote device. The position of the two-dimensional reference shape that is displayed or overlaid may be constant, even as the camera angle and obtained images change. Thus, a user may be guided to move the camera such that the fiducial reference aligns to (e.g., behind) the overlaid two-dimensional reference shape.

At **530**, the method **500** includes determining compliance with a set camera angle for the camera assembly of the remote device. In particular, it may be determined if the set camera angle is met.

As an example, a plurality of angle readings may be obtained (e.g., from a measurement device of the remote device) to determine the position of the remote device (e.g., relative to the washing machine appliance or a fixed reference direction, axis, or point). Subsequently, determined position of the remote device may be determined to match the set camera angle, or at least a portion thereof (e.g., within a set tolerance or range, such as 10%).

As an additional or alternative example, the detected fiducial reference may be compared to the two-dimensional reference shape. From the comparison, it may be determined if the fiducial reference matches the two-dimensional reference shape (e.g., the fiducial reference has dimensions that are within a set tolerance or range of the two-dimensional reference shape, such as 10%). For instance, the size or eccentricity of the fiducial reference within the obtained image may be calculated and compared to the size or eccentricity programmed for the two-dimensional reference shape.

If the set angle is met, such as may be indicated by using the plurality of angle readings or comparing the fiducial reference the two-dimensional reference shape, the method **500** may proceed to **540**. By contrast, if the set angle is not met, the method **500** may proceed to **534** (e.g., before returning to **520**).

At **534**, the method **500** includes displaying movement guidance (e.g., in the form of pictorial or textual instructions, such as arrows or written messages) with the real-time feed (e.g., to help a user move the camera to align the two-dimensional reference shape with the fiducial reference).

At **540**, the method **500** includes analyzing the obtained image using a machine learning image recognition process to estimate a load attribute of a load of clothes within the washing machine appliance based on the analysis. As used herein, the term "load attribute" and the like is intended to refer to any qualitative or quantitative characteristic of clothes within the wash chamber. For example, the load attribute may refer to a fabric type, a load color (such as white, light, dark, or mixed), or a load size (e.g., volume, mass, weight, etc.). In addition, it should be appreciated that the load attribute may be an approximation or best fit representation of a load of clothes. For example, a controller may be programmed with thresholds for determining whether a load qualifies as a white load, such as greater than 70% whites, greater than 80% whites, greater than 90% whites, greater than 95% whites, etc.).

In addition to providing approximations regarding primary load attributes such as type of fabric, color, and size, **540** may further include extracting information regarding outliers relative to the average load attribute. For example, if a load is detected as being primarily white or light colors, an outlier may be a single dark garment within the load (e.g., such as a red sock within a load of whites). In addition, **540** may include extracting or identifying unwashable items, such as a belt, a wallet, or another item which was likely inadvertently added into the wash chamber. In sum, **540** may be used for determining any suitable load attribute or other feature of a load of clothes that may be useful in adjusting the operation of washing machine appliance to achieve a better outcome, such as improved efficiency, improved wash performance, etc.

As used herein, the terms image recognition, object detection, and similar terms may be used generally to refer to any suitable method of observation, analysis, image decomposition, feature extraction, image classification, etc. of one or more image or videos taken within a wash chamber of a washing machine appliance. It should be appreciated that any suitable image recognition software or process may be used to analyze images taken by the camera assembly and a controller may be programmed to perform such processes and take corrective action.

In certain embodiments, the image analysis may include utilizing artificial intelligence ("AI"), such as a machine learning image recognition process, a neural network classification module, any other suitable artificial intelligence (AI) technique, or any other suitable image analysis techniques, examples of which will be described in more detail below. Moreover, each of the exemplary image analysis or evaluation processes described below may be used independently, collectively, or interchangeably to extract detailed information regarding the images being analyzed to facilitate performance of one or more methods described herein or to otherwise improve appliance operation. According to exemplary embodiments, any suitable number and combination of image processing, image recognition, or other image analysis techniques may be used to obtain an accurate analysis of the obtained images.

In this regard, the image recognition process may use any suitable artificial intelligence technique, for example, any suitable machine learning technique, or for example, any suitable deep learning technique. According to an exemplary embodiment, controller may implement a form of image recognition called region based convolutional neural network ("R-CNN") image recognition. Generally speaking, R-CNN may include taking an input image and extracting region proposals that include a potential object, such as an item of clothing (e.g., jeans, socks, etc.) or an undesirable article (e.g., a belt, a wallet, etc.). In this regard, a "region proposal" may be regions in an image that could belong to a particular object. A convolutional neural network is then used to compute features from the regions proposals and the extracted features will then be used to determine a classification for each particular region.

According to still other embodiments, an image segmentation process may be used along with the R-CNN image recognition. In general, image segmentation creates a pixel-based mask for each object in an image and provides a more detailed or granular understanding of the various objects within a given image. In this regard, instead of processing an entire image—i.e., a large collection of pixels, many of which might not contain useful information-image segmentation may involve dividing an image into segments (e.g., into groups of pixels containing similar attributes) that may be analyzed independently or in parallel to obtain a more detailed representation of the object or objects in an image. This may be referred to herein as "mask R-CNN" and the like. It should be appreciated that any other suitable image recognition process may be used while remaining within the scope of the present subject matter.

According to still other embodiments, the image recognition process may use any other suitable neural network process. For example, **540** may include using Mask R-CNN instead of a regular R-CNN architecture. In this regard, Mask R-CNN is based on Fast R-CNN which is slightly different than R-CNN. For example, R-CNN first applies CNN and then allocates it to zone recommendations on the covn5 property map instead of the initially split into zone recommendations. In addition, according to exemplary embodiments standard CNN may be used to analyze the image and estimate load size or main load fabric type of the load within the wash basket. In addition, a K-means algorithm may be used for dominant color analysis to find individual color of fabrics to serve with warnings.

According to exemplary embodiments the image recognition process may further include the implementation of Vision Transformer (ViT) techniques or models. In this regard, ViT is generally intended to refer to the use of a vision model based on the Transformer architecture originally designed and commonly used for natural language processing or other text-based tasks. For example, ViT represents an input image as a sequence of image patches and directly predicts class labels for the image. This process may be similar to the sequence of word embeddings used when applying the Transformer architecture to text. The ViT model and other image recognition models described herein may be trained using any suitable source of image data in any suitable quantity. Notably, ViT techniques have been demonstrated to outperform many state-of-the-art neural network or artificial intelligence image recognition processes.

According to still other embodiments, the image recognition process may use any other suitable neural network process while remaining within the scope of the present subject matter. For example, the step of analyzing the one or more images may include using a deep belief network ("DBN") image recognition process. A DBN image recognition process may generally include stacking many individual unsupervised networks that use each network's hid-

den layer as the input for the next layer. According to still other embodiments, the step of analyzing one or more images may include the implementation of a deep neural network ("DNN") image recognition process, which generally includes the use of a neural network (computing systems inspired by the biological neural networks) with multiple layers between input and output. Other suitable image recognition processes, neural network processes, artificial intelligence analysis techniques, and combinations of the above described or other known methods may be used while remaining within the scope of the present subject matter.

In addition, it should be appreciated that various transfer techniques may be used but use of such techniques is not required. If using transfer techniques learning, a neural network architecture may be pretrained such as VGG16/VGG19/ResNet50 with a public dataset then the last layer may be retrained with an appliance specific dataset. In addition, or alternatively, the image recognition process may include detection of certain conditions based on comparison of initial conditions, may rely on image subtraction techniques, image stacking techniques, image concatenation, etc. For example, the subtracted image may be used to train a neural network with multiple classes for future comparison and image classification.

It should be appreciated that the machine learning image recognition models may be actively trained by the appliance with new images, may be supplied with training data from the manufacturer or from another remote source, or may be trained in any other suitable manner. For example, according to exemplary embodiments, this image recognition process relies at least in part on a neural network trained with a plurality of images of the appliance in different configurations, experiencing different conditions, or being interacted with in different manners. This training data may be stored locally or remotely and may be communicated to a remote server for training other appliances and models. According to exemplary embodiments, it should be appreciated that the machine learning models may include supervised or unsupervised models and methods. In this regard, for example, supervised machine learning methods (e.g., such as targeted machine learning) may help identify problems, anomalies, or other occurrences which have been identified and trained into the model. By contrast, unsupervised machine learning methods may be used to detect clusters of potential failures, similarities among data, event patterns, abnormal concentrations of a phenomenon, etc.

It should be appreciated that image processing and machine learning image recognition processes may be used together to facilitate improved image analysis, object detection, color detection, or to extract other useful qualitative or quantitative data or information from the one or more images that may be used to improve the operation or performance of the appliance. Indeed, the methods described herein may use any or all of these techniques interchangeably to improve image analysis process and facilitate improved appliance performance and consumer satisfaction. The image processing algorithms and machine learning image recognition processes described herein are only exemplary and are not intended to limit the scope of the present subject matter in any manner.

At **550**, the method **500** includes selecting a wash cycle based on the estimated load attribute. The wash cycle includes settings that may be contingent, for instance, on the estimated load attribute (or attributes). Thus, **550** may include selecting an operating cycle parameter, adjusting a water or detergent fill amount, or providing a user notification. As used herein, an "operating parameter" of the washing machine appliance is any cycle setting, operating time, component setting, spin speed, part configuration, or other operating characteristic that may affect the performance of the washing machine appliance. In turn, references to operating parameter adjustments or "adjusting at least one operating parameter" are intended to refer to control actions intended to improve system performance based on the load characteristics. For example, adjusting an operating parameter may include adjusting an agitation time or an agitation profile, adjusting a water level, limiting a spin speed of the wash basket, etc. Other operating parameter adjustments are possible and within the scope of the present subject matter.

At **560**, the method **500** includes initiating a user confirmation (e.g., at the remote device). The user confirmation may include a visual alert on the monitor, haptic movement at the remote appliance, audio tone, etc. Moreover, the user confirmation may be prompted by or in response to one of the previous steps (e.g., **530**, **540**, or **550**). In optional embodiments, a feedback signal is generated (e.g., at the remote device) in response to the match being determined. Such a feedback signal may prompt the user confirmation such that a user can know further movement of the camera is unnecessary.

At **570**, it may be determined if the door to the washing machine appliance being closed within a predetermined time period (e.g., less than one minute, such as a period less than or equal to 30 seconds, 15 seconds, or 5 seconds) following one or more of the previous steps (e.g., **510**, **530**, **540**, **550**, or **560**). Such as determination may be based on a signal from the latch assembly or a subsequently received image from the camera assembly. If the door is shut within the predetermined time period, the method **500** may proceed to **580**. By contrast, if the door fails to shut (i.e., be closed) within the predetermined time period, the method **500** may proceed to **574** (e.g., before proceeding to **580**).

At **574**, the method includes detecting a user input at the washing machine appliance. Such a detection may be made, for instance, in response a user pressing a button or other suitable input feature on the control panel of the washing machine appliance.

At **580**, the method includes directing the selected wash cycle. Specifically, the washing machine appliance may start and further execute the selected wash cycle, as would be understood in light of the present disclosure.

This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they include structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. A method of operating a washing machine appliance, the washing machine appliance comprising a cabinet, a wash tub, and a wash basket, the wash tub being mounted within the cabinet, and the wash basket being rotatably mounted within a wash tub and defining a wash chamber configured for receiving a load of clothes, the method comprising:

obtaining one or more images of the washing machine appliance from a camera assembly of a remote device spaced apart from the cabinet;

receiving a plurality of angle readings from the remote device independent of the one or more images;

determining a position of the remote device relative to the washing machine appliance based on the plurality of angle readings;

determining a set camera angle for the camera assembly is met based on the determined position of the remote device;

analyzing at least one obtained image using a machine learning image recognition process;

estimating a load attribute of a load of clothes within the washing machine appliance based on the analysis; and

directing a wash cycle within the washing machine appliance based on the estimated load attribute,

wherein directing comprises selecting an operating cycle parameter or adjusting a water or detergent fill amount and dispensing water to the wash chamber according to the selected operating cycle parameter or adjusted water or fill amount,

wherein the plurality of angle readings are detected at a measuring device fixed to the remote device,

wherein the measuring device comprises an accelerometer, and

wherein the plurality of angle readings comprise a plurality of acceleration signals received from the accelerometer.

2. The method of claim **1**, wherein the load attribute comprises at least one of a fabric type, a load color, or a load size.

3. The method of claim **1**, further comprising:

determining a door of the washing machine appliance is open prior to determining the set camera angle is met.

4. The method of claim **1**, further comprising:

determining a door of the washing machine appliance is closed within a predetermined time period following obtaining one or more images of the washing machine appliance,

wherein directing the wash cycle is in response to determining the door is closed within the predetermined time period.

5. The method of claim **1**, further comprising:

generating a feedback signal prompting a feedback action at the remote device in response to determining the set camera angle is met.

6. The method of claim **1**, wherein obtaining one or more images comprises receiving a video signal from the camera assembly, and wherein the method further comprises

presenting a real-time feed of the camera assembly at the remote device according to the received video signal; and

overlaying a two-dimensional reference shape over the real-time feed.

7. The method of claim **1**, wherein obtaining one or more images comprises receiving a video signal from the camera assembly, and wherein the method further comprises

presenting a real-time feed of the camera assembly at the remote device according to the received video signal; and

displaying movement guidance with the real-time feed to guide the remote device to the set camera angle.

8. The method of claim **1**, wherein the machine learning image recognition process comprises at least one of a convolution neural network ("CNN"), a region-based convolution neural network ("R-CNN"), a deep belief network ("DBN"), a deep neural network ("DNN"), or a vision transformer ("ViT") image recognition process.

9. A method of operating a washing machine appliance, the washing machine appliance comprising a cabinet, a wash tub, and a wash basket, the wash tub being mounted within the cabinet, and the wash basket being rotatably mounted within a wash tub and defining a wash chamber configured for receiving a load of clothes, the method comprising:

obtaining one or more images of the washing machine appliance from a camera assembly of a remote device spaced apart from the cabinet, obtaining one or more images comprising receiving a video signal from the camera assembly;

presenting a real-time feed of the camera assembly at the remote device according to the received video signal;

receiving a plurality of angle readings from the remote device, the angle readings being relative to gravity and independent of the one or more images;

determining a position of the remote device relative to the washing machine appliance based on the plurality of angle readings;

overlaying a two-dimensional reference shape over the real-time feed;

determining a set camera angle for the camera assembly is met based on the determined position of the remote device;

analyzing at least one obtained image using a machine learning image recognition process;

estimating a load attribute of a load of clothes within the washing machine appliance based on the analysis, the load attribute comprising at least one of a fabric type, a load color, or a load size; and

directing a wash cycle within the washing machine appliance based on the estimated load attribute,

wherein directing comprises selecting an operating cycle parameter or adjusting a water or detergent fill amount and dispensing water to the wash chamber according to the selected operating cycle parameter or adjusted water or fill amount,

wherein the plurality of angle readings are detected at a measuring device fixed to the remote device,

wherein the measuring device comprises an accelerometer, and

wherein the plurality of angle readings comprise a plurality of acceleration signals received from the accelerometer.

10. The method of claim **9**, further comprising:

determining a door of the washing machine appliance is open prior to determining the set camera angle is met.

11. The method of claim **9**, further comprising:

determining a door of the washing machine appliance is closed within a predetermined time period following obtaining one or more images of the washing machine appliance,

wherein directing the wash cycle is in response to determining the door is closed within the predetermined time period.

12. The method of claim **9**, further comprising:

generating a feedback signal prompting a feedback action at the remote device in response to determining the set camera angle is met.

13. The method of claim **9**, wherein the method further comprises

displaying movement guidance with the real-time feed to guide the remote device to the set camera angle.

14. The method of claim **9**, wherein the machine learning image recognition process comprises at least one of a convolution neural network ("CNN"), a region-based convolution neural network ("R-CNN"), a deep belief network

("DBN"), a deep neural network ("DNN"), or a vision transformer ("ViT") image recognition process.

15. A method of operating a washing machine appliance, the washing machine appliance comprising a cabinet, a wash tub, a wash basket, and a spout, the wash tub being mounted within the cabinet, the wash basket being rotatably mounted within a wash tub and defining a wash chamber configured for receiving a load of clothes, and the spout directed at the wash chamber to permit water thereto, the method comprising:

obtaining one or more images of the washing machine appliance from a camera assembly of a remote device spaced apart from the cabinet, obtaining one or more images comprising receiving a video signal from the camera assembly;

presenting a real-time feed of the camera assembly at the remote device according to the received video signal;

receiving a plurality of angle readings from the remote device, the angle readings being relative to gravity and independent of the one or more images;

determining a position of the remote device relative to the washing machine appliance based on the plurality of angle readings;

overlaying a two-dimensional reference shape over the real-time feed;

determining a door of the washing machine appliance is open;

determining a set camera angle for the camera assembly is met based on the determined position of the remote device and the door being determined to be open;

analyzing at least one obtained image using a machine learning image recognition process;

estimating a load attribute of a load of clothes within the washing machine appliance based on the analysis, the load attribute comprising at least one of a fabric type, a load color, or a load size; and

directing a wash cycle within the washing machine appliance based on the estimated load attribute,

wherein directing comprises selecting an operating cycle parameter or adjusting a water or detergent fill amount and dispensing water to the wash chamber from the spout according to the selected operating cycle parameter or adjusted water or fill amount,

wherein the measuring device comprises an accelerometer, and

wherein the plurality of angle readings comprise a plurality of acceleration signals received from the accelerometer.

16. The method of claim **15**, wherein the determined position is a second determined position, wherein the method further comprises

determining, prior to the determined second position, a first position of the remote relative to the washing machine appliance based on the plurality of angle readings;

determining the set camera angle for the camera assembly is met, the set camera angle is not met based on the determined first position; and

displaying movement guidance with the real-time feed to guide the remote device to the set camera angle in response to determining the set camera angle is not met.

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