US 20230118322A1

(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2023/0118322 A1

Yoon et al. (43) Pub. Date: Apr. 20, 2023

(54) SYSTEMS AND METHODS FOR USING ARTIFICIAL INTELLIGENCE FOR IMPROVED RINSE CYCLES IN A WASHING MACHINE APPLIANCE

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(21) Appl. No.: **17/501,204**

(22) Filed: **Oct. 14, 2021**

Publication Classification

(51) **Int. Cl.**

D06F 33/38 (2006.01)

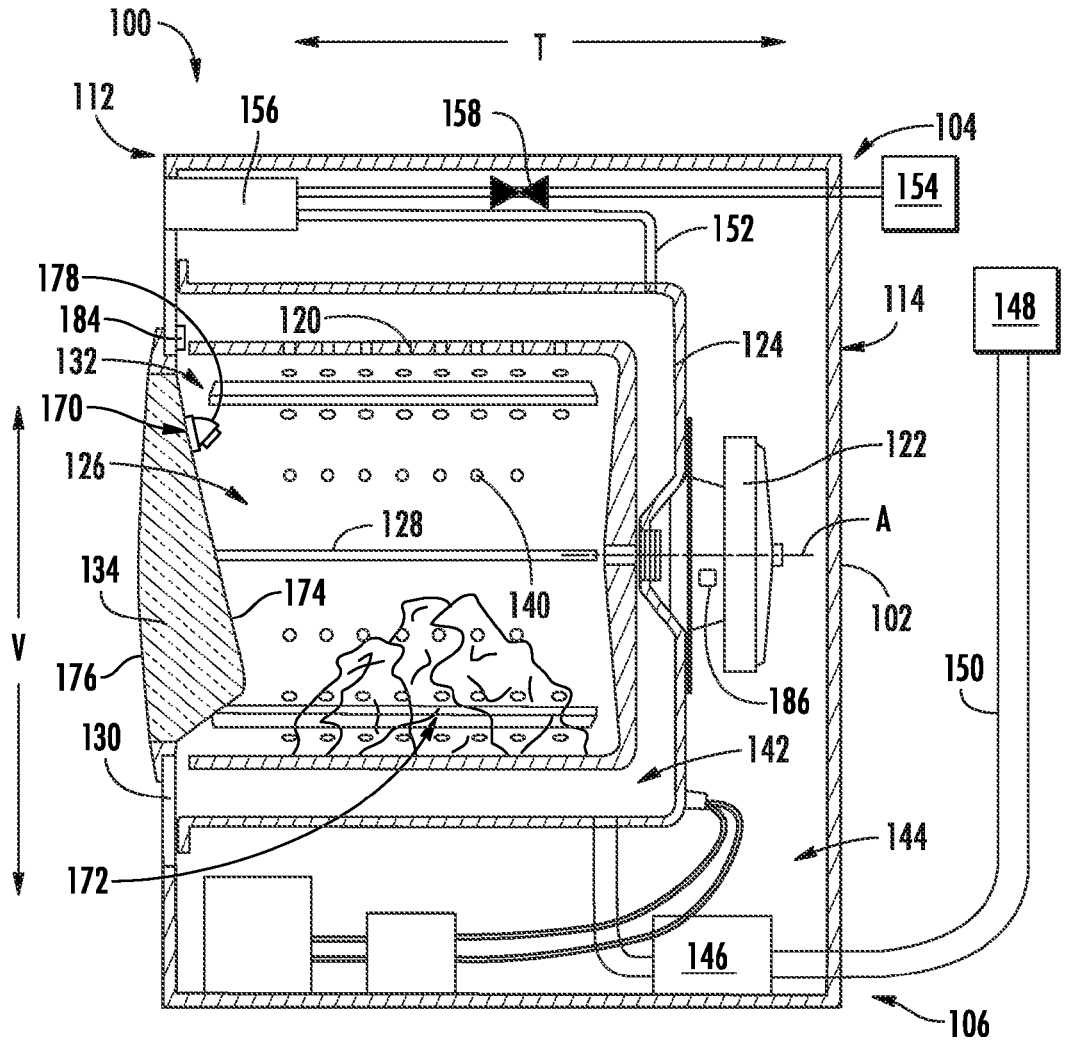
D06F 34/22 (2006.01)

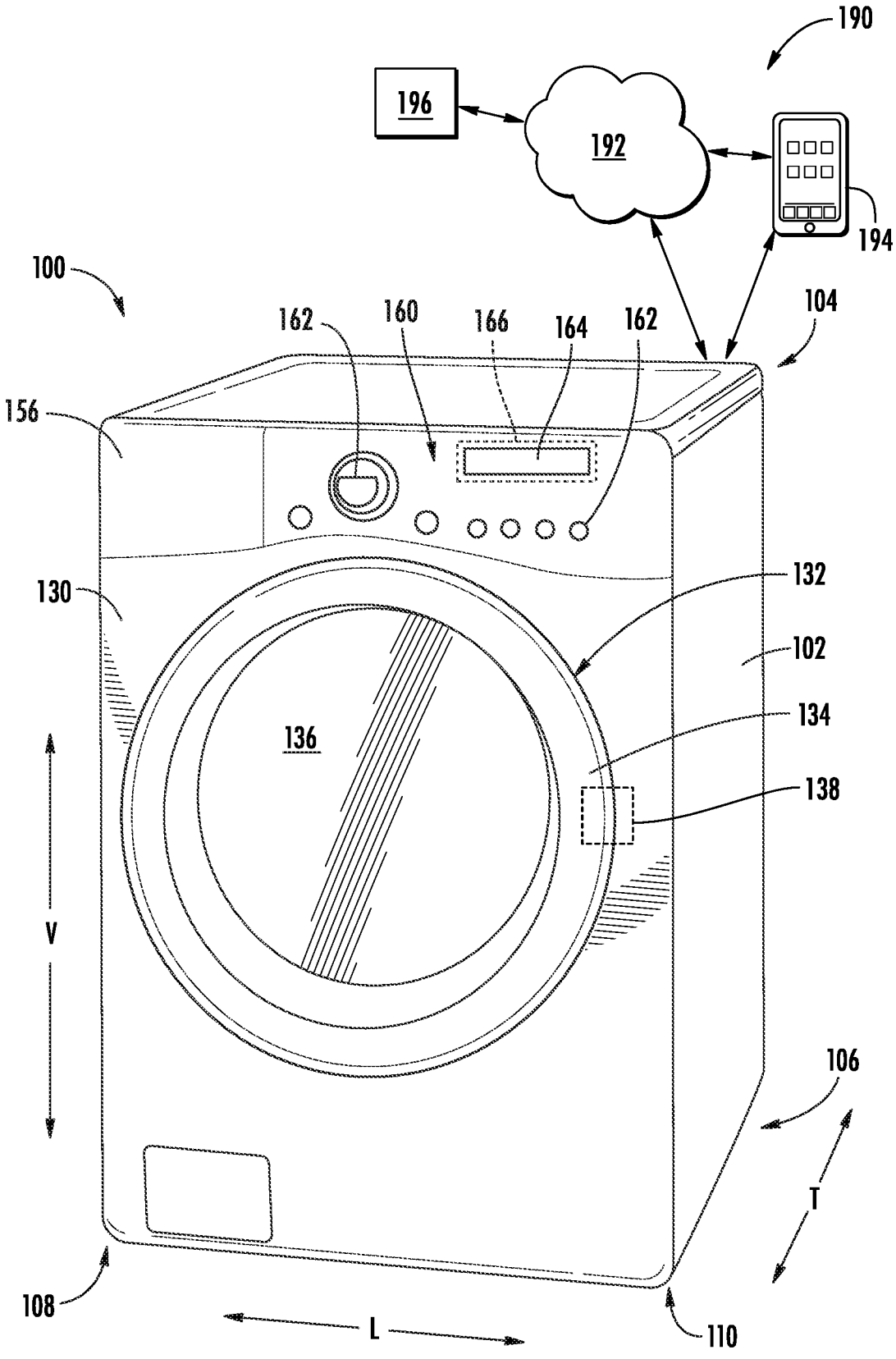
(52) **U.S. Cl.**

CPC ***D06F 33/38*** (2020.02); ***D06F 34/22*** (2020.02); *D06F 21/04* (2013.01)

(57) **ABSTRACT**

A washing machine appliance includes a wash basket that is rotatably mounted within a wash tub and that defines a wash chamber for receiving a load of clothes. A dispensing assembly selectively dispenses wash fluid through a discharge nozzle into the wash tub and a camera assembly is used to monitor the load of clothes and diagnose the presence of excessive bubbles after a wash cycle. Specifically, a controller of the washing machine appliance uses the camera assembly to obtain one or more images of the load of clothes after the drain phase of the wash cycle and analyzes the one or more images using a machine learning image recognition process to determine a bubble level within the wash tub. If the bubble level is greater than a predetermined bubble threshold, corrective action is taken to reduce the bubbles and detergent concentration.




190
196
192
194
100
104
162
160
166
164
162
156
130
132
102
136
134
138
V
106
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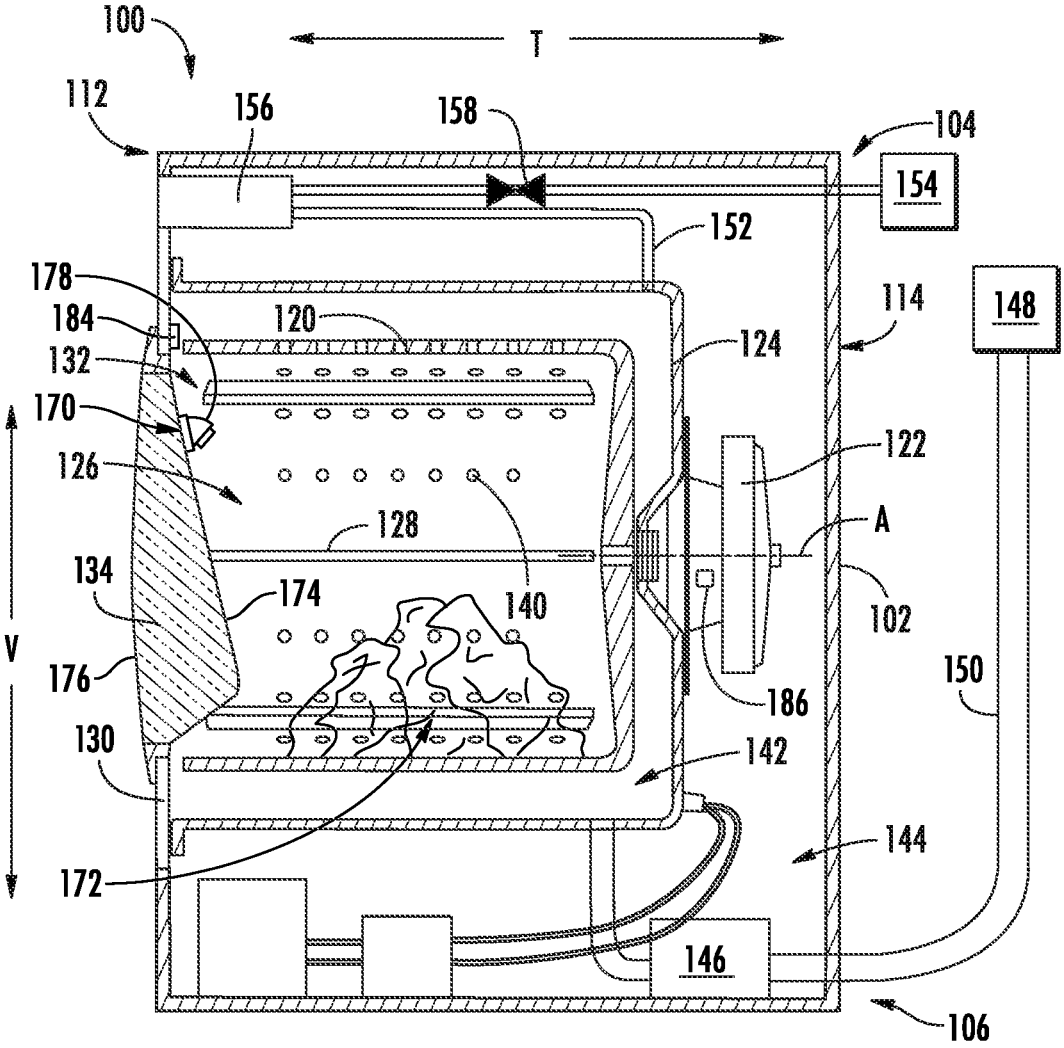
108
L
110

FIG. 1


100
T
112
156
158
104
154
152
178
184
120
114
148
132
124
170
122
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128
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134
174
140
102
V
176
150
186
130
142
144
172
146
106

FIG. 2

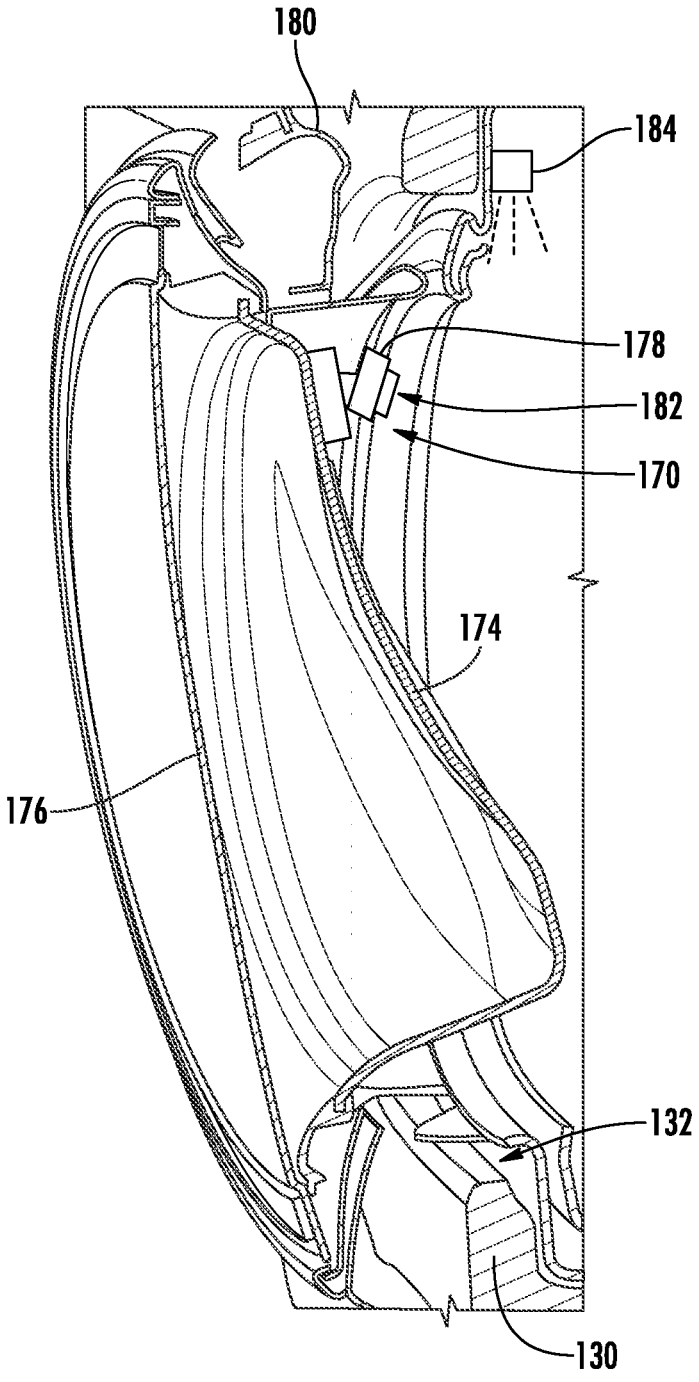

FIG. 3

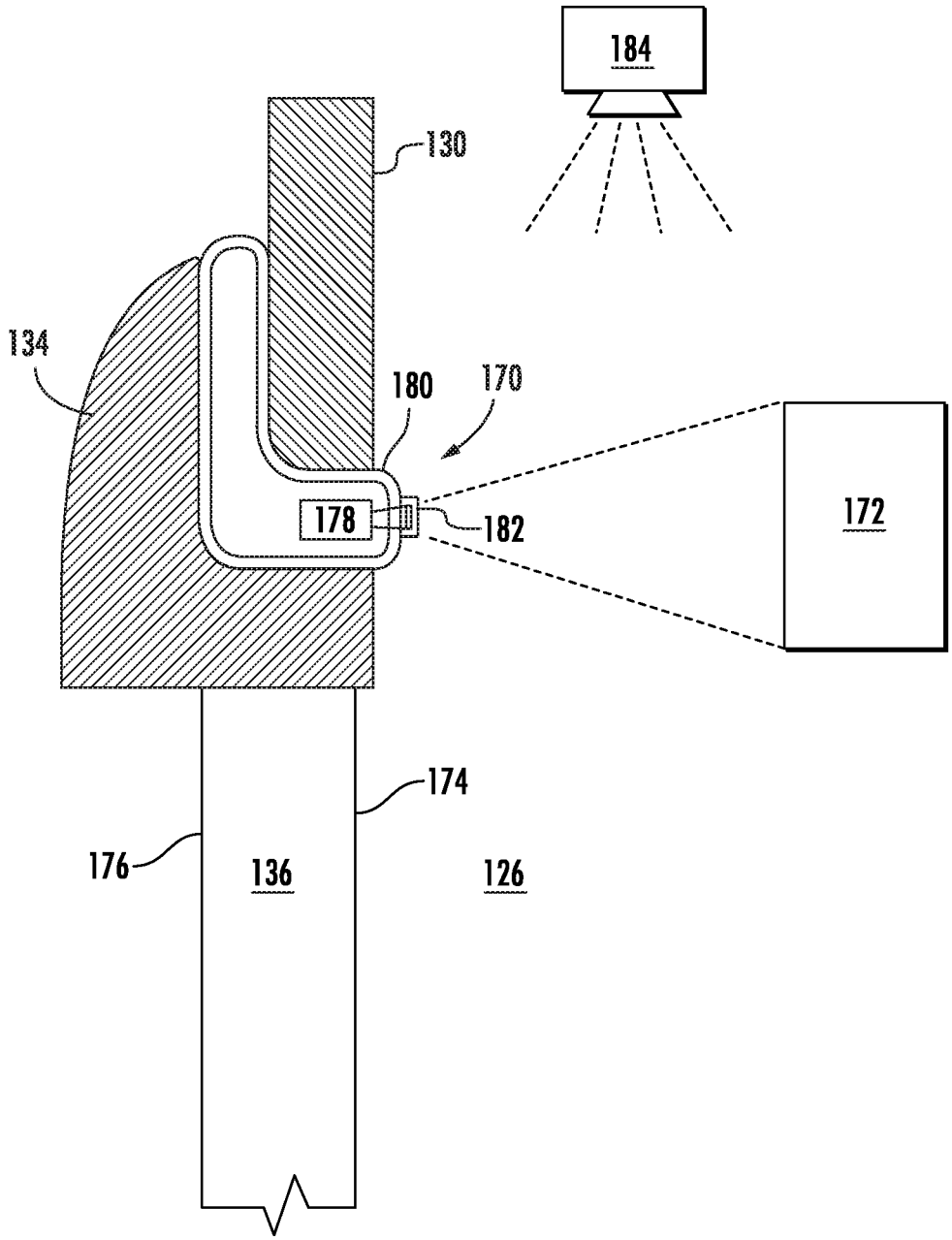

FIG. 4

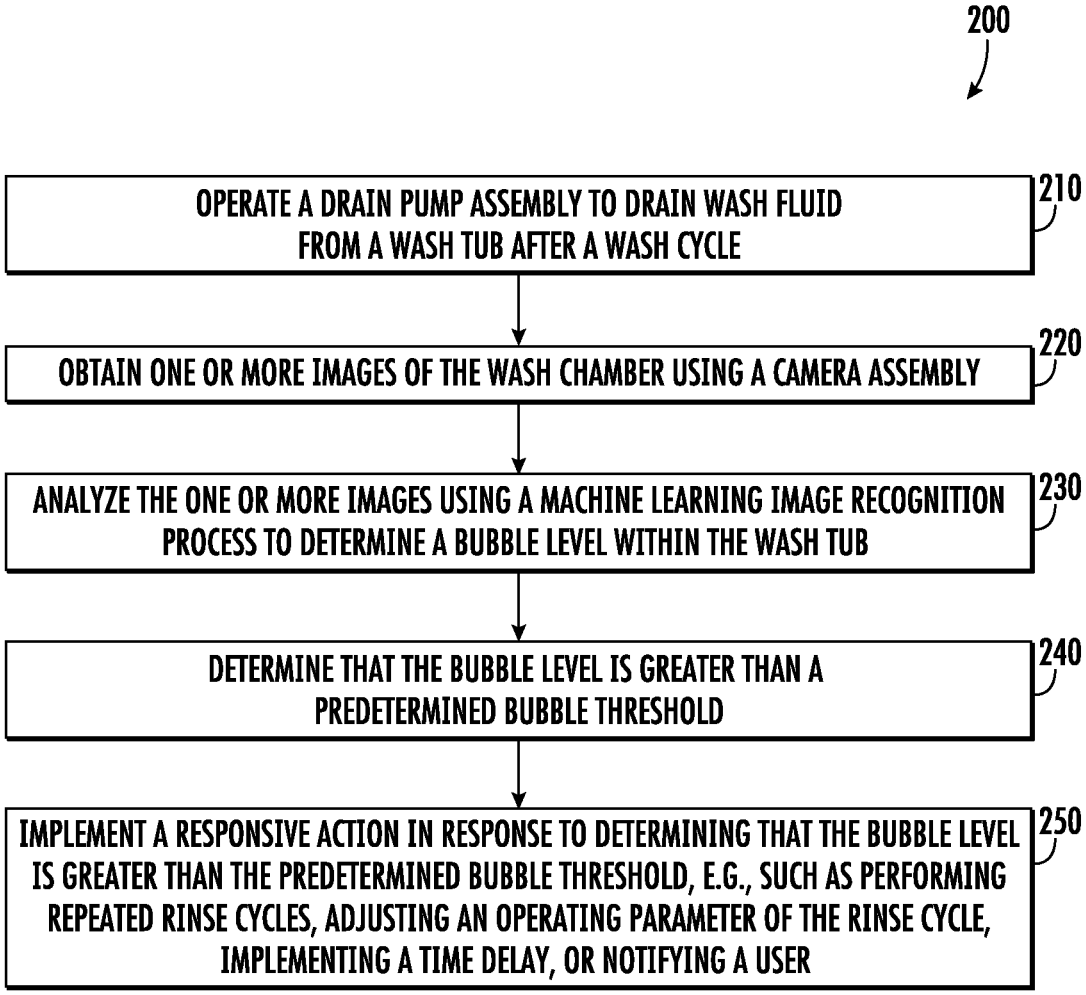
200
OPERATE A DRAIN PUMP ASSEMBLY TO DRAIN WASH FLUID FROM A WASH TUB AFTER A WASH CYCLE
210
OBTAIN ONE OR MORE IMAGES OF THE WASH CHAMBER USING A CAMERA ASSEMBLY
220
ANALYZE THE ONE OR MORE IMAGES USING A MACHINE LEARNING IMAGE RECOGNITION PROCESS TO DETERMINE A BUBBLE LEVEL WITHIN THE WASH TUB
230
DETERMINE THAT THE BUBBLE LEVEL IS GREATER THAN A PREDETERMINED BUBBLE THRESHOLD
240
IMPLEMENT A RESPONSIVE ACTION IN RESPONSE TO DETERMINING THAT THE BUBBLE LEVEL IS GREATER THAN THE PREDETERMINED BUBBLE THRESHOLD, E.G., SUCH AS PERFORMING REPEATED RINSE CYCLES, ADJUSTING AN OPERATING PARAMETER OF THE RINSE CYCLE, IMPLEMENTING A TIME DELAY, OR NOTIFYING A USER
250

FIG. 5

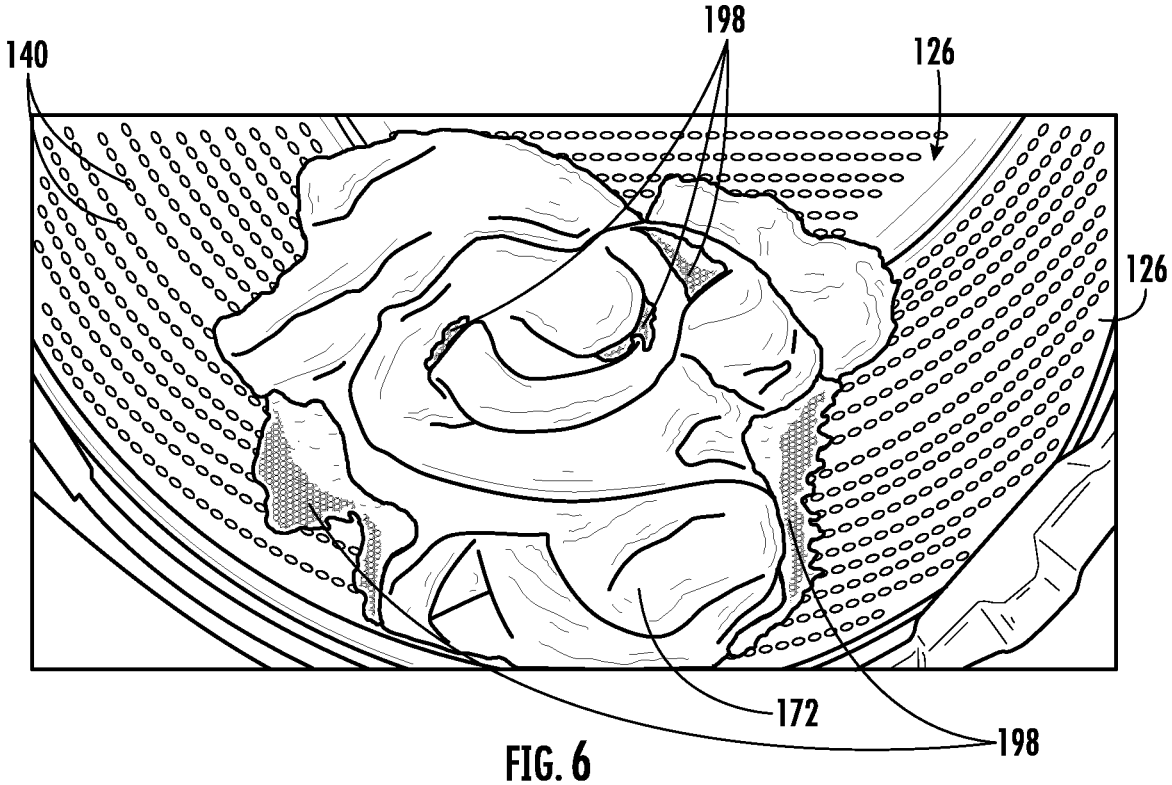

FIG. 6

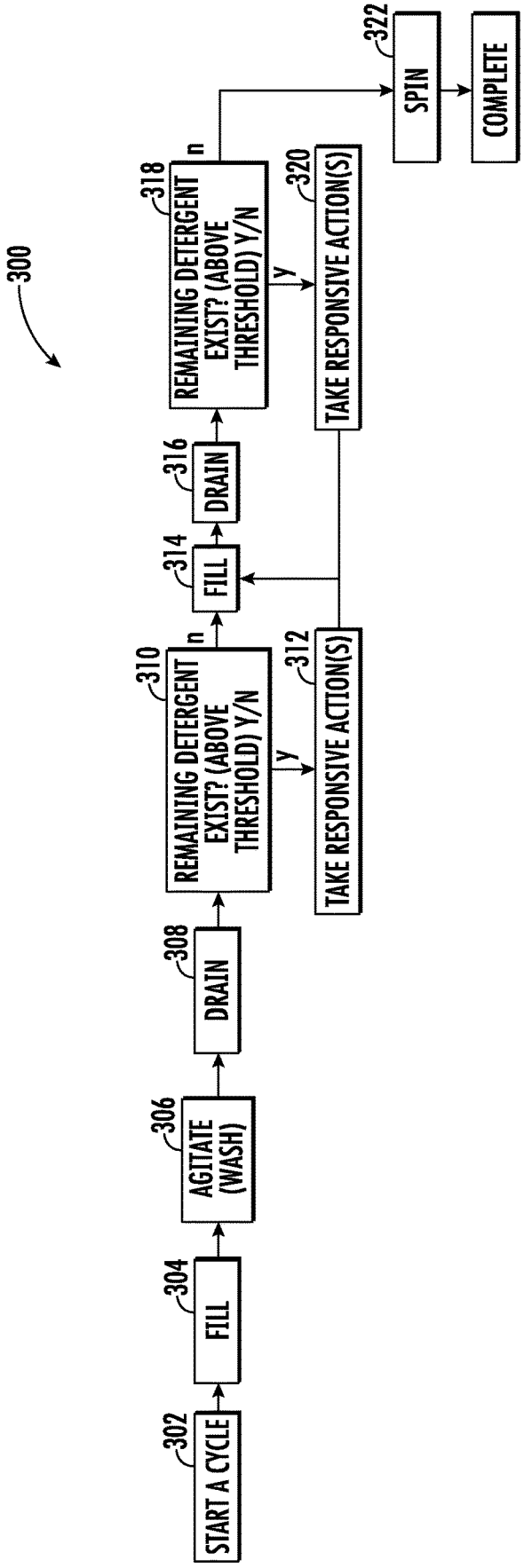
300
302
START A CYCLE
304
FILL
306
AGITATE (WASH)
308
DRAIN
310
REMAINING DETERGENT EXIST? (ABOVE THRESHOLD) Y/N
n
y
312
TAKE RESPONSIVE ACTION(S)
314
FILL
316
DRAIN
318
REMAINING DETERGENT EXIST? (ABOVE THRESHOLD) Y/N
n
y
320
TAKE RESPONSIVE ACTION(S)
322
SPIN
COMPLETE

FIG. 7

SYSTEMS AND METHODS FOR USING ARTIFICIAL INTELLIGENCE FOR IMPROVED RINSE CYCLES IN A WASHING MACHINE APPLIANCE

FIELD OF THE INVENTION

[0001] The present subject matter relates generally to washing machine appliances, or more specifically, to systems and methods for using image recognition processes to improve rinse performance in a washing machine appliance.

BACKGROUND OF THE INVENTION

[0002] Washing machine appliances generally include a cabinet which receives a wash tub for containing water or wash fluid (e.g., water and detergent, bleach, or other wash additives). The wash tub may be suspended within the cabinet by a suspension system to allow some movement relative to the cabinet during operation. A wash basket is rotatably mounted within the wash tub and defines a wash chamber for receipt of articles for washing. A drive assembly is coupled to the wash tub and is configured to selectively rotate the wash basket within the wash tub.

[0003] Detergent and other additives are commonly added to the wash tub to form a wash fluid that facilitates a wash cycle. For example, a user may add detergent directly into the wash tub or into a dispenser reservoir where it is flushed with water into the wash tub. By contrast, certain conventional washing machine appliances are equipped with a bulk dispensing detergent system that includes a bulk reservoir for storing a large amount of detergent. A detergent dispenser can inject a particular amount of detergent based on the load size, water level, and load type to facilitate a wash operation.

[0004] Whether the detergent is supplied manually or through a smart dispense system, it is possible that too much detergent gets added into the wash tub. For example, a user might not have a good idea on the optimal detergent amount to add to the tub. Alternatively, a smart dispense feature may be available, but the user may add additional detergent without knowing the feature is available. In addition, the wrong type of detergent may be inadvertently added to the wash tub, e.g., accidental use of dish soap, use of concentrated detergent instead of regular, etc. If too much detergent or the wrong type of detergent is added for a wash cycle, conventional rinse cycles may fail to remove all the detergent from the load of clothes, which may cause some issues on the consumer side (e.g., skin irritation).

[0005] Accordingly, a washing machine appliance with improved rinse performance is desirable. More specifically, a washing machine appliance that is capable of detecting situations where excess detergent remains after a wash cycle would be particularly beneficial.

BRIEF DESCRIPTION OF THE INVENTION

[0006] Advantages of the invention will be set forth in part in the following description, or may be apparent from the description, or may be learned through practice of the invention.

[0007] In one exemplary embodiment, a washing machine appliance is provided including a wash tub positioned within a cabinet, a wash basket rotatably mounted within the wash tub and defining a wash chamber configured for receiving a load of clothes, a dispensing assembly configured to selectively dispense wash fluid through a discharge nozzle into the wash tub, a drain pump assembly fluidly coupled to the wash tub for selectively draining the wash fluid from the wash tub, a camera assembly mounted within the cabinet in view of the wash basket, and a controller operably coupled to the dispensing assembly, the drain pump assembly, and the camera assembly. The controller is configured to operate the drain pump assembly to drain the wash fluid from the wash tub after a wash cycle, obtain one or more images of the wash chamber using the camera assembly, analyze the one or more images using a machine learning image recognition process to determine a bubble level within the wash tub, determine that the bubble level is greater than a predetermined bubble threshold, and implement a responsive action in response to determining that the bubble level is greater than the predetermined bubble threshold.

[0008] In another exemplary embodiment, a method of operating a washing machine appliance is provided. The washing machine appliance includes a wash basket rotatably mounted within a wash tub and defining a wash chamber configured for receiving a load of clothes, a dispensing assembly configured to selectively dispense wash fluid through a discharge nozzle into the wash tub, a drain pump assembly fluidly coupled to the wash tub for selectively draining the wash fluid from the wash tub, and a camera assembly mounted within in view of the wash basket. The method includes operating the drain pump assembly to drain the wash fluid from the wash tub after a wash cycle, obtaining one or more images of the wash chamber using the camera assembly, analyzing the one or more images using a machine learning image recognition process to determine a bubble level within the wash tub, determining that the bubble level is greater than a predetermined bubble threshold, and implementing a responsive action in response to determining that the bubble level is greater than the predetermined bubble threshold.

[0009] 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

[0010] 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.

[0011] FIG. **1** provides a perspective view of an exemplary washing machine appliance according to an exemplary embodiment of the present subject matter.

[0012] FIG. **2** provides a side cross-sectional view of the exemplary washing machine appliance of FIG. **1**.

[0013] FIG. **3** provides a cross-sectional view of the exemplary washing machine appliance of FIG. **1** with a camera assembly mounted on a door according to an exemplary embodiment of the present subject matter.

[0014] FIG. **4** provides a schematic view of a door and gasket sealed against a cabinet of the exemplary washing machine of FIG. **1**, along with a camera mounted within the gasket according to an exemplary embodiment of the present subject matter.

[0015] FIG. **5** illustrates a method for operating a washing machine appliance in accordance with one embodiment of the present disclosure.

[0016] FIG. **6** provides an image captured by the exemplary camera assembly of FIG. **3** with excess remaining detergent according to an exemplary embodiment of the present disclosure.

[0017] FIG. **7** provides a flow diagram illustrating an exemplary process for implementing an adaptive rinse cycle according to an exemplary embodiment of the present subject matter.

[0018] 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

[0019] 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 or spirit 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.

[0020] 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 and/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.

[0021] 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 and/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.

[0022] 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.

[0023] The terms "wash fluid" and the like may be used herein to generally refer to a liquid used for washing and/or rinsing clothing or other articles. For example, the wash fluid is typically made up of water that may include other additives such as detergent, fabric softener, bleach, or other suitable treatments (including combinations thereof). By contrast, the term "water" is intended to refer to water only with no detergent, additives, etc. According to exemplary embodiments, the wash fluid for a wash cycle may be a mixture of water, detergent, and/or other additives, while the wash fluid for a rinse cycle may be water only.

[0024] 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. Washing machine appliance **100** includes a cabinet **102** that extends between a top **104** and a bottom **106** along the vertical direction V, between a left side **108** and a right side **110** along the lateral direction, and between a front **112** and a rear **114** along the transverse direction T.

[0025] 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**.

[0026] 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**.

[0027] 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**.

[0028] 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** and/or door **134** for selectively locking door **134** in the closed position and/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.

[0029] 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**.

[0030] 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**.

[0031] 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 **154** (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**.

[0032] 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.

[0033] In addition, a water supply valve **158** may provide a flow of water from a water supply source (such as a municipal water supply **154**) 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.

[0034] A control panel **160** including a plurality of input selectors **162** is coupled to front panel **130**. Control panel **160** and input selectors **162** collectively form a user interface input for operator selection of machine cycles and features. For example, in one embodiment, a display **164** indicates selected features, a countdown timer, and/or other items of interest to machine users. Operation of washing machine appliance **100** is controlled by a controller or processing device **166** (FIG. **1**) that is operatively coupled to control panel **160** for user manipulation to select washing machine cycles and features. In response to user manipulation of control panel **160**, controller **166** operates the various components of washing machine appliance **100** to execute selected machine cycles and features.

[0035] Controller **166** may include a memory and microprocessor, such as a general or special purpose microprocessor operable to execute programming instructions or micro-control code associated with a cleaning cycle. The memory may represent random access memory such as DRAM, or read only memory such as ROM or FLASH. In one embodiment, the processor executes programming instructions stored in memory. The memory may be a separate component from the processor or may be included onboard within the processor. Alternatively, controller **166** may be constructed without using a microprocessor, e.g., using a combination of discrete analog and/or digital logic circuitry (such as switches, amplifiers, integrators, comparators, flip-flops, AND gates, and the like) to perform control functionality instead of relying upon software. Control panel **160** and other components of washing machine appliance **100** may be in communication with controller **166** via one or more signal lines or shared communication busses.

[0036] 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 input selectors **162**. Wash tub **124** is filled with water, detergent, and/or other fluid additives, e.g., via spout **152** and/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 and/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**.

[0037] 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 and/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, and/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**.

[0038] Referring now specifically to FIGS. **2** and **3**, washing machine appliance **100** may further include a camera assembly **170** that is generally positioned and configured for obtaining images of wash chamber **126** or a load of clothes (e.g., as identified schematically by reference numeral **172**) within wash chamber **126** of washing machine appliance **100**. Specifically, according to the illustrated embodiment, door **134** of washing machine appliance **100** comprises and inner window **174** that partially defines wash chamber **126** and an outer window **176** that is exposed to the ambient environment. According to the illustrated exemplary embodiment, camera assembly **170** includes a camera **178** that is mounted to inner window **174**. Specifically, camera **178** is mounted such that is faces toward a bottom side of wash tub **124**. In this manner, camera **178** can take images or video of an inside of wash chamber **126** and remains unobstructed by windows that may obscure or distort such images.

[0039] Referring now briefly to FIG. **4**, another installation of camera assembly **170** will be described according to an exemplary embodiment of the present subject matter. Due to the similarity between this and other embodiments, like reference numerals may be used to refer to the same or similar features. According to this exemplary embodiment, camera assembly **170** is mounted within a gasket **180** that is positioned between a front panel **130** of cabinet **102** and door **134**. Although exemplary camera assemblies **170** are illustrated and described herein, it should be appreciated that according to alternative embodiments, washing machine appliance **100** may include any other camera or system of imaging devices for obtaining images of the load of clothes **172** or wash chamber **126**.

[0040] It should be appreciated that camera assembly **170** may include any suitable number, type, size, and configuration of camera(s) **178** for obtaining images of wash chamber **126**. In general, cameras **178** may include a lens **182** that is constructed from a clear hydrophobic material or which may otherwise be positioned behind a hydrophobic clear lens. So positioned, camera assembly **170** may obtain one or more images or videos of clothes **172** within wash chamber **126**, as described in more detail below. Referring still to FIGS. **2** through **4**, washing machine appliance **100** may further include a tub light **184** that is positioned within cabinet **102** or wash chamber **126** for selectively illuminating wash chamber **126** and/or the load of clothes **172** positioned therein.

[0041] According to exemplary embodiments of the present subject matter, washing machine appliance **100** may further include a basket speed sensor **186** (FIG. **2**) that is generally configured for determining a basket speed of wash basket **120**. In this regard, for example, basket speed sensor **186** may be an optical, tactile, or electromagnetic speed sensor that measures a motor shaft speed (e.g., such as a tachometer, hall-effect sensor, etc.). According to still other embodiments, basket speeds may be determined by measuring a motor frequency, a back electromotive force (EMF) on motor **122**, or a motor shaft speed in any other suitable manner. Accordingly, it should be appreciated that according to exemplary embodiments, a physical basket speed sensor **186** is not needed, as electromotive force and motor frequency may be determined by controller **166** without needing a physical speed sensor. It should be appreciated that other systems and methods for monitoring basket speeds may be used while remaining within the scope of the present subject matter.

[0042] Notably, controller **166** of washing machine appliance **100** (or any other suitable dedicated controller) may be communicatively coupled to camera assembly **170**, tub light **184**, latch assembly **138**, and other components of washing machine appliance **100**. As explained in more detail below, controller **166** may be programmed or configured for obtaining images using camera assembly **170**, e.g., in order to detect certain operating conditions and improve the performance of washing machine appliance, e.g., such as initiating an adaptive rinse cycle upon analyzing images of the load of clothes after the wash cycle using a machine learning image recognition process.

[0043] Referring still to FIG. **1**, a schematic diagram of an external communication system **190** will be described according to an exemplary embodiment of the present subject matter. In general, external communication system **190** is configured for permitting interaction, data transfer, and other communications with washing machine appliance **100**. For example, this communication may be used to provide and receive operating parameters, cycle settings, performance characteristics, user preferences, user notifications, or any other suitable information for improved performance of washing machine appliance **100**.

[0044] External communication system **190** permits controller **166** of washing machine appliance **100** to communicate with external devices either directly or through a network **192**. For example, a consumer may use a consumer device **194** to communicate directly with washing machine appliance **100**. For example, consumer devices **194** may be in direct or indirect communication with washing machine appliance **100**, e.g., directly through a local area network (LAN), Wi-Fi, Bluetooth, Zigbee, etc. or indirectly through network **192**. In general, consumer device **194** may be any suitable device for providing and/or receiving communications or commands from a user. In this regard, consumer device **194** may include, for example, a personal phone, a tablet, a laptop computer, or another mobile device.

[0045] In addition, a remote server **196** may be in communication with washing machine appliance **100** and/or consumer device **194** through network **192**. In this regard, for example, remote server **196** may be a cloud-based server **196**, and is thus located at a distant location, such as in a separate state, country, etc. In general, communication between the remote server **196** and the client devices may be carried via a network interface using any type of wireless

connection, using a variety of communication protocols (e.g., TCP/IP, HTTP, SMTP, FTP), encodings or formats (e.g., HTML, XML), and/or protection schemes (e.g., VPN, secure HTTP, SSL).

[0046] In general, network **192** can be any type of communication network. For example, network **192** can include one or more of a wireless network, a wired network, a personal area network, a local area network, a wide area network, the internet, a cellular network, etc. According to an exemplary embodiment, consumer device **194** may communicate with a remote server **196** over network **192**, such as the internet, to provide user inputs, transfer operating parameters or performance characteristics, receive user notifications or instructions, etc. In addition, consumer device **194** and remote server **196** may communicate with washing machine appliance **100** to communicate similar information.

[0047] External communication system **190** 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 **190** 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 laundry 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.

[0048] While described in the context of a specific embodiment of horizontal axis washing machine appliance **100**, using the teachings disclosed herein it will be understood that horizontal axis washing machine appliance **100** is provided by way of example only. Other washing machine appliances having different configurations, different appearances, and/or different features may also be utilized with the present subject matter as well, e.g., vertical axis washing machine appliances. In addition, aspects of the present subject matter may be utilized in a combination washer/dryer appliance.

[0049] Now that the construction of washing machine appliance **100** and the configuration of controller **166** according to exemplary embodiments have been presented, an exemplary method **200** of operating a washing machine appliance will be described. Although the discussion below refers to the exemplary method **200** of operating washing machine appliance **100**, one skilled in the art will appreciate that the exemplary method **200** is 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 by controller **166** or a separate, dedicated controller.

[0050] Referring now to FIG. **5**, method **200** includes, at step **210**, operating a drain pump assembly to drain wash fluid from a wash tub after a wash cycle. In this regard, using washing machine appliance **100** as an example, a typical wash cycle may include filling wash tub **124** with wash fluid that contains both water and detergent. The wash cycle may further include agitating the load of clothes **172** within wash basket **120**, e.g., by operating drive motor to rotate wash basket **120**, thereby facilitating an agitation and cleaning process. After the agitation and cleaning portion of the wash cycle is complete, the wash cycle proceeds to drain the wash fluid from wash tub **124** to complete the wash cycle. Subsequently, a rinse cycle may be performed to remove residual detergent from the load of clothes **172**.

[0051] However, as explained above, if the wrong type or amount of detergent is added to the wash fluid during the wash phase, an undesirable amount of bubbles may be generated that may be difficult or impossible to remove with a conventional rinse cycle. In addition, these bubbles may be a visual indicator as to the presence of an excessive amount of detergent within the load of clothes **172** or within wash tub **124** after the wash cycle has been completed. Aspects of the present subject matter are directed to detecting such a condition in implementing corrective action.

[0052] Specifically, step **220** may include obtaining one or more images of the wash chamber using a camera assembly. In this regard, for example, camera **178** of camera assembly **170** may be oriented such that it has a field of view that encompasses the load of clothes **184** positioned within wash basket **120** (e.g., as shown for example in FIG. **6**). As explained in more detail below, these images may be used to determine whether excessive bubbles or detergent are present in the wash tub **124** and/or on the load of clothes **172**. By identifying excessive bubbles at this stage, the rinse portion (s) of the appliance operating cycle may be modified for improved detergent removal.

[0053] Thus, step **220** includes obtaining one or more images, a series of frames, a video, or any other visual representation of the load of clothes **172** within wash basket **120**. For example, camera assembly **170** may obtain a video clip of the load of clothes **172**, take a still image from the video clip, or otherwise obtain a still representation or photo from the video clip. It should be appreciated that the images obtained by camera assembly **170** may vary in number, frequency, angle, resolution, detail, etc. in order to improve the clarity of the load of clothes. In addition, according to exemplary embodiments, controller **166** may be configured for illuminating the tub using tub light **184** just prior to obtaining images.

[0054] Referring still to FIG. **5**, method **200** may include, at step **230**, analyzing the one or more images using a machine learning image recognition process to determine whether excessive bubbles or detergent are present in the wash tub. It should be appreciated that any suitable image processing or recognition method may be used to analyze the images obtained at step **220** and facilitate determination of the actual bubble/detergent content. In addition, it should be appreciated that this image analysis or processing may be performed locally (e.g., by controller **166**) or remotely (e.g., by a remote server).

[0055] According to exemplary embodiments of the present subject matter, step **230** of analyzing the one or more images may include analyzing the image(s) of the wash fluid using a neural network classification module and/or a machine learning image recognition process. In this regard, for example, controller **166** may be programmed to implement the machine learning image recognition process that includes a neural network trained with a plurality of images of a load of clothes after being washed with wash fluid with different detergent concentrations or volumes, images of wash basket **120** containing different amounts of bubbles, etc. By analyzing the image(s) obtained at step **220** using this machine learning image recognition process, controller **156** may determine or approximate the actual bubble or

detergent content within the load of clothes or wash tub, e.g., by identifying the trained image that is closest to the obtained image.

[0056] As used herein, the terms image recognition process 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 images or videos taken within a washing machine appliance. In this regard, the image recognition process may use any suitable artificial intelligence (AI) technique, for example, any suitable machine learning technique, or for example, any suitable deep learning technique. It should be appreciated that any suitable image recognition software or process may be used to analyze images taken by camera assembly **170** and controller **166** may be programmed to perform such processes and take corrective action.

[0057] 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 a particular region containing a load of clothes that is covered in bubbles or where the water is particularly hazy or cloudy. In this regard, a "region proposal" may be regions in an image that could belong to a particular object, such as a particular grouping of detergent bubbles. 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.

[0058] 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.

[0059] According to still other embodiments, the image recognition process may use any other suitable neural network process. For example, step **230** 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 covn**5** 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 determine an actual bubble level within the wash tub. In addition, a K-means algorithm may be used. Other image recognition processes are possible and within the scope of the present subject matter.

[0060] It should be appreciated that any other suitable image recognition process may be used while remaining within the scope of the present subject matter. For example, step **230** 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, step **230** 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 ("AI") 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.

[0061] Referring now briefly to FIG. **6**, an exemplary image obtained by camera assembly **170** will be provided according to an exemplary embodiment. For example, FIG. **6** illustrates load of clothes **172** positioned within wash basket **120** after a wash cycle. Specifically, the image shown is exemplary of a wash cycle that was performed with too much detergent or the wrong type of detergent, such that an excessive amount of detergent bubbles (e.g., identified herein generally by reference numeral **198**) remain after completion of a wash cycle. Notably, if this operating cycle proceeded directly to a conventional rinse cycle, it is possible that the remaining detergent would not be properly removed from the load of clothes **172**, which may result in skin irritation and general dissatisfaction of the washing machine performance.

[0062] Accordingly, step **230** may include an artificial intelligence or machine learning image classification process that classifies the load of clothes **172** and/or the wash basket **120** as containing no detergent bubbles, excessive detergent bubbles, or some quantification there between. For example, the bubble level might be low when the detergent used in the wash cycle was appropriate, such that the image contains minimal bubbles or distortion. By contrast, FIG. **6** illustrates a relatively large amount of bubbles (e.g., or otherwise includes hazy, cloudy, bubbly, or opaque portions), indicating that the user has added too much detergent or the wrong kind of detergent prior to initiating the wash cycle.

[0063] Although the bubble content is described above as being a classification of an image as either showing the absence or presence of bubbles, it should be appreciated that the determination of the bubble content may vary while remaining within the scope of the present subject matter. For example, some bubbles might be expected or okay after a wash cycle. Accordingly, controller **166** may be programmed with a predetermined bubble threshold that may be used to determine whether too much residual detergent or bubbles are present.

[0064] In this regard, step **240** may include determining that the bubble level detected at step **230** is greater than a predetermined bubble threshold. As noted above, this condition may be associated with the presence of too much residual detergent after the wash cycle. Although the analysis described in steps **230** and **240** is described above as being performed with respect to a single image, it should be appreciated that this analysis may be extended to a video stream, a plurality of images, or any other visual representation of the of the load of clothes **172**. Notably, if too many bubbles are present, it may be desirable to take corrective action.

[0065] Accordingly, step **250** may include implementing a responsive action in response to determining that the bubble

level is greater than the predetermined bubble threshold. In general, the responsive action may be intended to reduce the amount of residual detergent or otherwise facilitate a rinse cycle where the remaining detergent falls below a suitable level. Although exemplary responsive actions are described below, it should be appreciated that variations and modifications may be made to step **250** while remaining within scope the present subject matter.

[0066] For example, according to an exemplary embodiment, implementing the responsive action may include performing a plurality of rinse cycles (e.g., as opposed to the conventional single rinse cycle). In addition, each of these rinse cycles may include adding a flow of fresh water into the wash tub, agitating the load of clothes by rotating the wash basket, and subsequently draining the tub. Alternatively, each of these steps may be performed simultaneously. In this regard, the responsive action may include simultaneously operating the dispensing assembly to provide a flow of water into the wash tub, agitating the load of clothes by rotating the wash basket, and draining the wash tub using the drain pump assembly.

[0067] According to still other embodiments, implementing the responsive action may include adjusting one or more operating parameters of the rinse cycle. For example, the temperature of the fresh water supply during the rinse cycle may be adjusted (e.g., increased or decreased relative to a conventional rinse cycle) to facilitate detergent breakdown and removal. In addition, or alternatively, the volume of water dispensed during a rinse cycle may be adjusted for example, it may be desirable to supply more fresh water into the wash tub during a rinse cycle to better dilute and remove the residual detergent.

[0068] According to still other embodiments, implementing the responsive action may be implementing a time delay to permit the bubbles within the wash tub to pop and/or otherwise dissipate on their own. In this regard, the time delay may be implemented after draining the wash fluid after the wash cycle before performing the rinse cycle (e.g., before injecting additional water). According to exemplary embodiments, the time delay after the draining phase of the wash cycle may be between about 10 seconds and 1 hour, between about 30 seconds and 30 minutes, between about 1 minute and 20 minutes, between about 2 minutes and 10 minutes, or about three minutes. Other time delays are possible and within scope the present subject matter.

[0069] In addition, step **250** of implementing a responsive action may further include providing a user notification that that the bubble level is greater than the predetermined bubble threshold. In addition, this user notification may include useful information such as estimated bubble levels, fault diagnosis, and/or suggested responsive action. It should be appreciated that the user notification may be provided to the user from any suitable source and in any suitable manner. For example, according to exemplary embodiments, the user notification may be provided through control panel **160** so that the user may be aware of the issue (e.g., such as via an illuminated warning indicator, an image displayed on a screen, etc.). In addition, or alternatively, controller **166** may be configured to provide a user notification to a remote device, such as remote device **194** via a network **192**. Whether provided via control panel **160**, remote device **194**, or by other means, this user notification may include useful information regarding the presence or absence of detergent bubbles or other useful information. For example, the user notification may include a pop-up notification on a user's cell phone or other remote device and may include a display of the one or more images with categorization of the bubble level in preset bubble threshold.

[0070] Notably, method **200** may further include taking no action when the bubble level is as desired. In this regard, method **200** may include determining that the bubble level is less than the predetermined bubble threshold and continuing with a normal operating cycle, e.g., such as initiating a standard rinse cycle. In addition, method **200** may include verifying that the responsive action was effective. In this regard, after implementing the responsive action, such as repeated rinse cycles or rinse cycles with different operating parameters, camera assembly may obtain one or more additional images that may be analyzed in the same manner described above to determine the bubble level within the wash tub. If the bubble level still remains above the predetermined bubble threshold, additional action may be taken. Otherwise, the operating cycle may proceed to the rinse cycle as usual.

[0071] Referring now briefly to FIG. **7**, an exemplary flow diagram of a bubble detection or adaptive rinse method **300** that may be implemented by washing machine appliance **100** will be described according to an exemplary embodiment of the present subject matter. According to exemplary embodiments, method **300** may be similar to or interchangeable with method **200** and may be implemented by controller **166** of washing machine appliance **100**. As shown, at step **302**, controller **166** may first start an operating cycle of a washing machine appliance.

[0072] Step **304** includes filling the wash tub with a flow of wash fluid containing both water and detergent. Step **306** generally includes performing an agitation phase of the wash cycle, e.g., by using the drive motor to rotate wash basket **120** and tumble the load of clothes contained therein. After the agitation cycle, step **308** may include operating a drain pump assembly to drain the wash fluid from the wash tub. Notably, as explained above, if an excessive amount of detergent or the wrong type of detergent were added to the wash tub during the wash cycle, there may be excessive residual detergent and detergent bubbles within the load of clothes **172** after step **308**. Accordingly, method **300** is generally directed to a process of detecting such a condition and facilitating an adaptive rinse cycle to correct this condition.

[0073] Specifically step **310** may include obtaining one or more images within the wash basket using a camera assembly and analyzing those images using a machine learning image recognition process. This analysis may conclude with a classification as to the bubble level within the load of clothes **172**. If the bubble level determined at step **310** exceeds a predetermined bubble threshold, responsive action may be taken at step **312**. As explained above, this responsive action may include performing repeated rinse cycles, performing rinse cycles with the adjusted operating parameters (e.g., such as increased water volumes or temperatures), implementing a time delay, notifying the user, etc.

[0074] If step **310** results in a determination that the bubble level does not exceed the bubble threshold, the operating cycle may proceed as usual toward the rinse cycle. In this regard, the rinse cycle may generally include step **314** of filling the wash tub with fresh water and subsequently draining that water and step **316**. According to exemplary embodiments, step **318** may include a post-rinse verification

that any remaining bubbles fall below a predetermined threshold. If the bubble level is still too high, step **320** may once again involve taking responsive actions (e.g., as described above). By contrast, if the post-rinse verification at step **318** results in a determination that the bubble level is below the threshold, the operating cycle may complete by performing a spin cycle at step **322**.

[0075] FIGS. **5** and **7** depict steps performed in a particular order for purposes of illustration and discussion. Those of ordinary skill in the art, using the disclosures provided herein, will understand that the steps of any of the methods discussed herein can be adapted, rearranged, expanded, omitted, or modified in various ways without deviating from the scope of the present disclosure. Moreover, although aspects of method **200** and method **300** are explained using washing machine appliance **100** as an example, it should be appreciated that this method may be applied to the operation of any suitable laundry appliance, such as another washing machine appliance.

[0076] The systems and methods described herein may utilize adaptive rinse cycles when excessive detergent is detected by obtaining images with a camera and analyzing those images using an artificial intelligence or machine learning classification technique. Specifically, a classification artificial intelligence technique is used to identify existing bubbles through the images acquired by the camera. For example, after a wash cycle, if residual detergent is recognized, responsive actions are taken, e.g., such as increasing the number of rinse cycles, performing drum agitation and draining simultaneously, increasing the temperature of the water to generate fewer bubbles or waiting until the bubbles have popped and then running the drain cycle. If no residual detergent is detected, the spinning operation may be performed and the cycle may be completed.

[0077] 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.

1. A washing machine appliance, comprising:

a wash tub positioned within a cabinet;

a wash basket rotatably mounted within the wash tub and defining a wash chamber configured for receiving a load of clothes;

a dispensing assembly configured to selectively dispense wash fluid through a discharge nozzle into the wash tub;

a drain pump assembly fluidly coupled to the wash tub for selectively draining the wash fluid from the wash tub;

a camera assembly mounted within the cabinet in view of the wash basket; and

a controller operably coupled to the dispensing assembly, the drain pump assembly, and the camera assembly, the controller being configured to:

operate the drain pump assembly to drain the wash fluid from the wash tub after a wash cycle;

obtain one or more images of the wash chamber using the camera assembly after operating the drain pump assembly to drain the wash fluid;

analyze the one or more images using a machine learning image recognition process to determine a bubble level within the wash tub;

determine that the bubble level is greater than a predetermined bubble threshold; and

implement a responsive action in response to determining that the bubble level is greater than the predetermined bubble threshold.

2. The washing machine appliance 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"), or a deep neural network ("DNN") image recognition process.

3. The washing machine appliance of claim **1**, wherein implementing the responsive action comprises:

performing a plurality of rinse cycles, wherein each of the plurality of rinse cycles comprises adding a flow of water into the wash tub and at least one of agitating the load of clothes by rotating the wash basket, spinning the wash basket, or draining the wash tub.

4. The washing machine appliance of claim **1**, wherein implementing the responsive action comprises:

adjusting a water temperature of a flow of water dispensed during a rinse cycle.

5. The washing machine appliance of claim **1**, wherein implementing the responsive action comprises:

adjusting a volume of water dispensed during a rinse cycle.

6. The washing machine appliance of claim **1**, wherein implementing the responsive action comprises:

implementing a time delay after draining the wash fluid and before performing a rinse cycle.

7. The washing machine appliance of claim **6**, wherein the time delay is between 1 minute and 30 minutes.

8. The washing machine appliance of claim **1**, wherein implementing the responsive action comprises:

simultaneously operating the dispensing assembly to provide a flow of water into the wash tub, agitate the load of clothes by rotating the wash basket, and draining the wash tub using the drain pump assembly.

9. The washing machine appliance of claim **1**, wherein implementing the responsive action comprises:

providing a user notification that the bubble level is greater than the predetermined bubble threshold.

10. The washing machine appliance of claim **9**, further comprising:

a user interface panel, wherein the user notification is provided through the user interface panel.

11. The washing machine appliance of claim **9**, wherein the controller is in operative communication with a remote device through an external network, and wherein the user notification is provided through the remote device.

12. The washing machine appliance of claim **1**, wherein the controller is further configured to:

determine that the bubble level is less than the predetermined bubble threshold; and

perform a rinse cycle.

13. The washing machine appliance of claim **1**, wherein the controller is further configured to:

obtain one or more additional images after implementing the responsive action;

analyze the one or more additional images using the machine learning image recognition process to determine a bubble level within the wash tub;

determine that the bubble level is greater than the predetermined bubble threshold; and

implement another responsive action in response to determining that the bubble level is greater than the predetermined bubble threshold.

14. The washing machine appliance of claim **1**, wherein the camera assembly has a field of view oriented toward a bottom of the wash basket where the load of clothes collects.

15. The washing machine appliance of claim **1**, wherein the camera assembly includes a light source for illuminating the wash chamber while obtaining the one or more images.

16. The washing machine appliance of claim **1**, wherein the washing machine appliance is a horizontal axis washing machine appliance.

17. A method of operating a washing machine appliance, the washing machine appliance comprising a wash basket rotatably mounted within a wash tub and defining a wash chamber configured for receiving a load of clothes, a dispensing assembly configured to selectively dispense wash fluid through a discharge nozzle into the wash tub, a drain pump assembly fluidly coupled to the wash tub for selectively draining the wash fluid from the wash tub, and a camera assembly mounted within in view of the wash basket, the method comprising:

operating the drain pump assembly to drain the wash fluid from the wash tub after a wash cycle;

obtaining one or more images of the wash chamber using the camera assembly after operating the drain pump assembly to drain the wash fluid;

analyzing the one or more images using a machine learning image recognition process to determine a bubble level within the wash tub;

determining that the bubble level is greater than a predetermined bubble threshold; and

implementing a responsive action in response to determining that the bubble level is greater than the predetermined bubble threshold.

18. The method of claim **17**, wherein implementing the responsive action comprises:

simultaneously operating the dispensing assembly to provide a flow of water into the wash tub, agitate the load of clothes by rotating the wash basket, and draining the wash tub using the drain pump assembly.

19. The method of claim **17**, wherein implementing the responsive action comprises:

providing a user notification that the bubble level is greater than the predetermined bubble threshold.

20. The method of claim **17**, further comprising:

determining that the bubble level is less than the predetermined bubble threshold; and

performing a rinse cycle.

* * * * *