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Doke et al.

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(54) **CONSERVING POWER IN ITEM-IDENTIFYING CARTS**

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(73) Assignee: **Amazon Technologies, Inc.**, Seattle, WA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 547 days.

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(22) Filed: **Jun. 29, 2022**

(51) **Int. Cl.**

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G06V 10/774	(2022.01)
G06V 10/776	(2022.01)
G06V 20/50	(2022.01)
G06V 40/10	(2022.01)
H04N 7/18	(2006.01)
G06Q 20/20	(2012.01)

(52) **U.S. Cl.**
CPC ***G06V 10/87*** (2022.01); ***G06V 10/774*** (2022.01); ***G06V 10/776*** (2022.01); ***G06V 20/50*** (2022.01); ***G06V 40/10*** (2022.01); ***H04N 7/188*** (2013.01); *G06Q 20/208* (2013.01)

(58) **Field of Classification Search**
CPC G06V 10/87; G06V 10/774; G06V 10/776; G06V 20/50; G06V 40/10; H04N 7/188; G06Q 20/208
See application file for complete search history.

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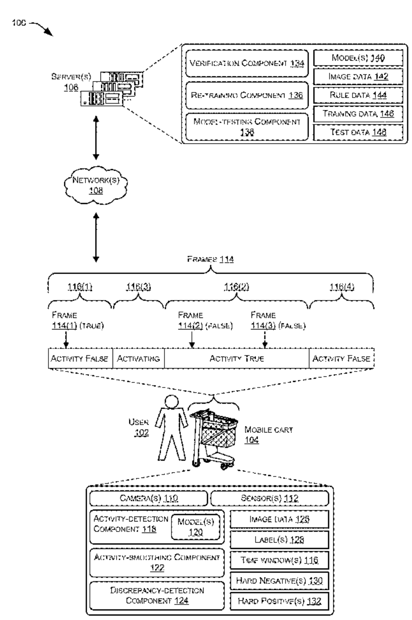
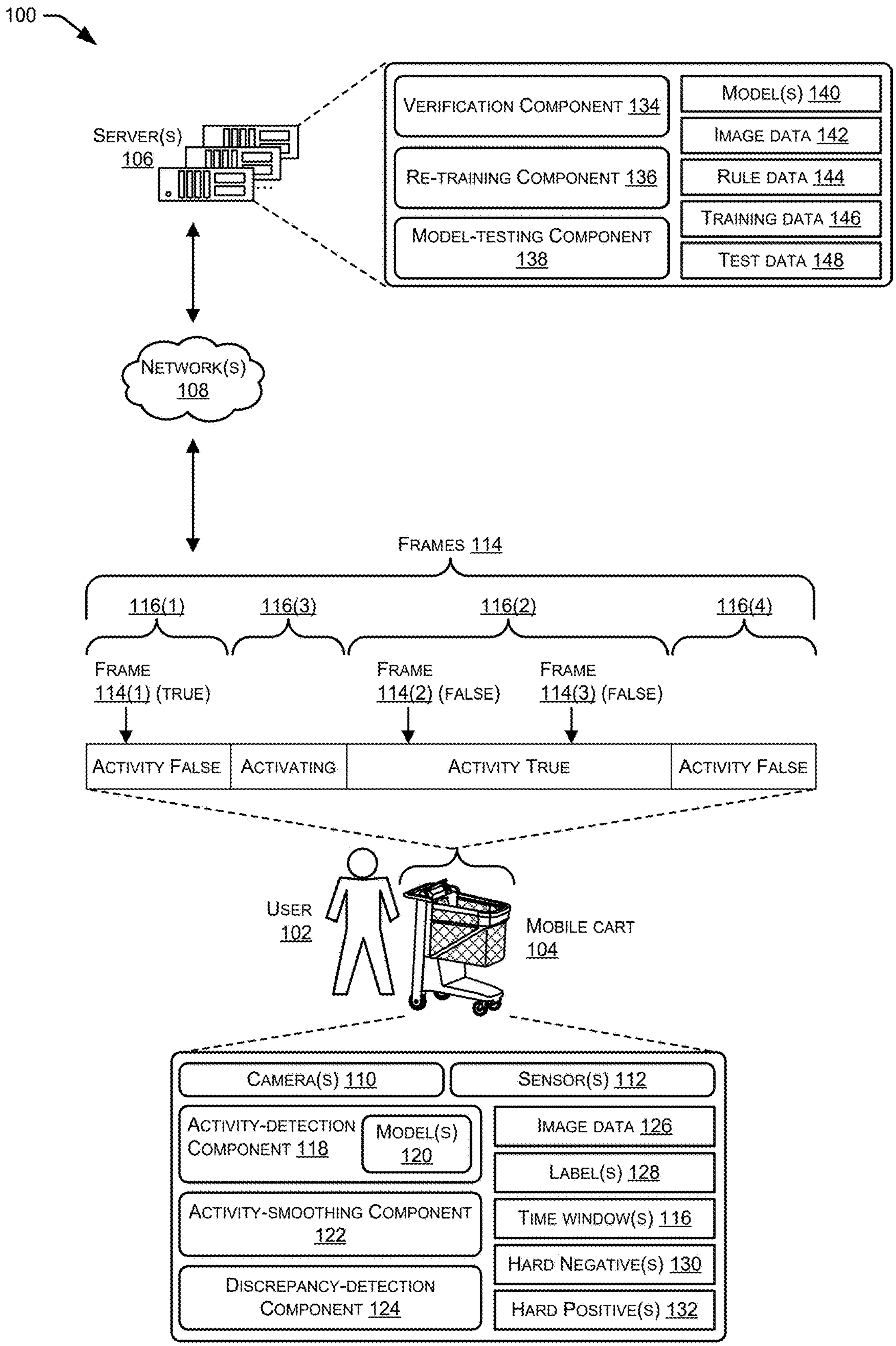
(74) *Attorney, Agent, or Firm* — Kilpatrick Townsend & Stockton LLP

(57) **ABSTRACT**

This disclosure is directed to an item-identifying, mobile cart that may be utilized by a user in a materials handling facility to automatically identify items that the user places into a basket of the cart. The cart may include cameras for detecting activity near a basket of the cart, such as a user placing an item into the basket. The cart or a computing device communicatively coupled to the cart may use a trained machine-learning model to identify the activity, and may improve the accuracy of the model over time using real-world data of users operating carts in respective facilities.

18 Claims, 19 Drawing Sheets

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Server(s) 106
Verification Component 134
Re-training Component 136
Model-testing Component 138
Model(s) 140
Image data 142
Rule data 144
Training data 146
Test data 148
Network(s) 108
Frames 114
116(1)
116(3)
116(2)
116(4)
Frame 114(1) (true)
Frame 114(2) (false)
Frame 114(3) (false)
Activity False
Activating
Activity True
Activity False
User 102
Mobile cart 104
Camera(s) 110
Sensor(s) 112
Activity-detection Component 118
Model(s) 120
Image data 126
Label(s) 128
Activity-smoothing Component 122
Time window(s) 116
Discrepancy-detection Component 124
Hard Negative(s) 130
Hard Positive(s) 132

FIG. 1

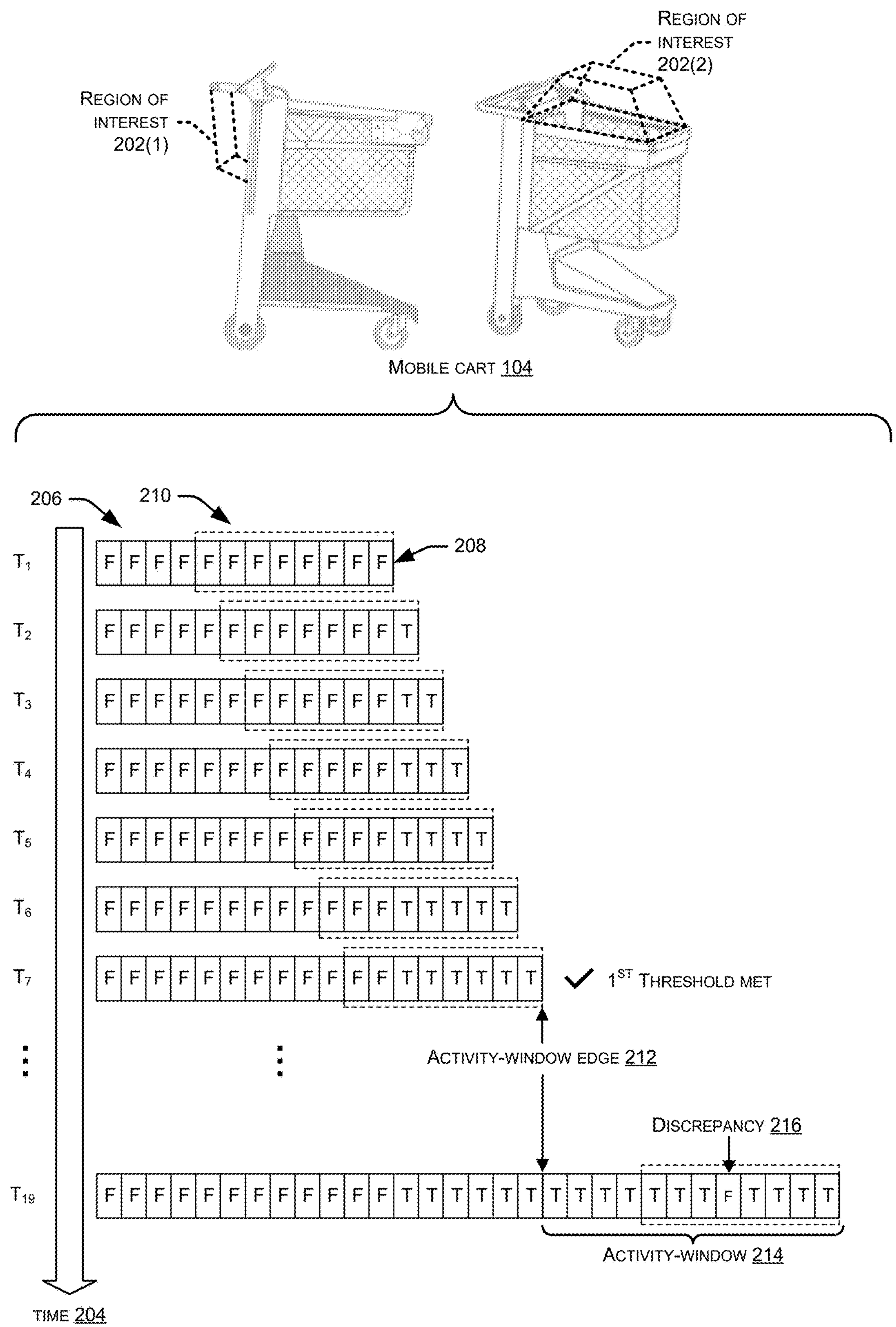

REGION OF INTEREST 202(1)
REGION OF INTEREST 202(2)
MOBILE CART 104
206
210
208
T1
T2
T3
T4
T5
T6
T7
T19
1ST THRESHOLD MET
ACTIVITY-WINDOW EDGE 212
DISCREPANCY 216
ACTIVITY-WINDOW 214
TIME 204

FIG. 2A

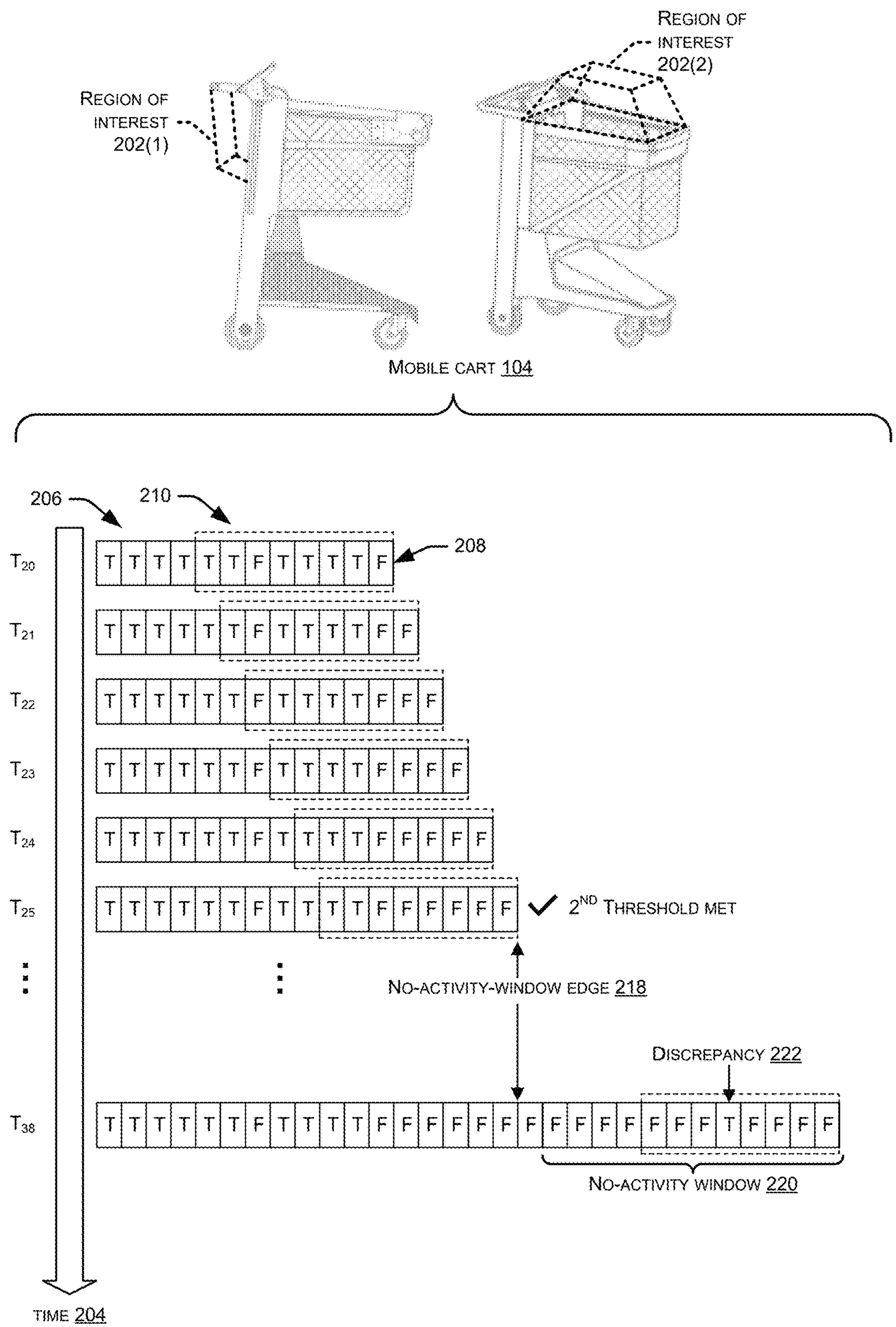

REGION OF INTEREST 202(1)
REGION OF INTEREST 202(2)
MOBILE CART 104
206
210
208
T20
T21
T22
T23
T24
T25
T38
2ND THRESHOLD MET
NO-ACTIVITY-WINDOW EDGE 218
DISCREPANCY 222
NO-ACTIVITY WINDOW 220
TIME 204

FIG. 2B

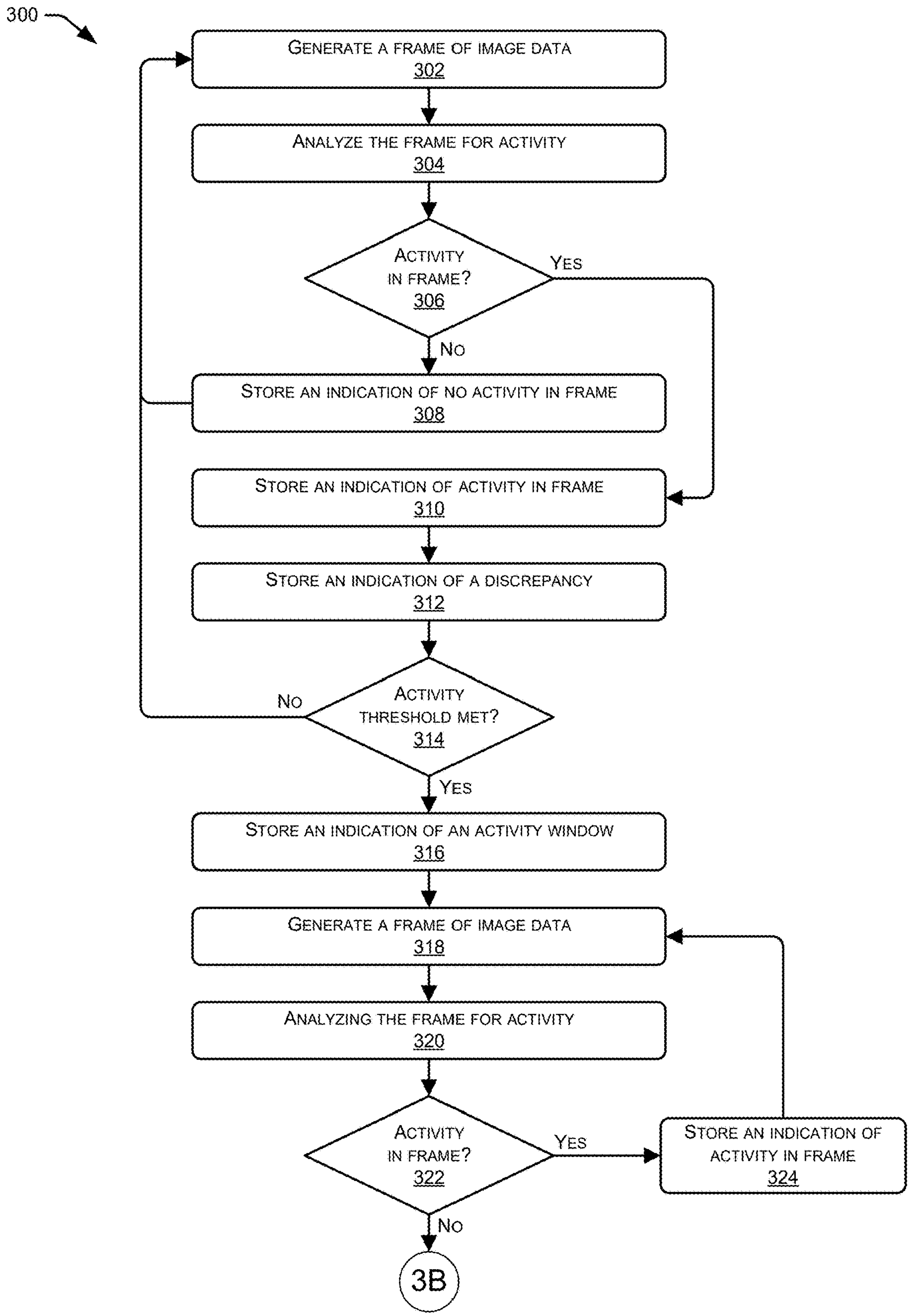

300
GENERATE A FRAME OF IMAGE DATA
302
ANALYZE THE FRAME FOR ACTIVITY
304
ACTIVITY
IN FRAME?
306
YES
NO
STORE AN INDICATION OF NO ACTIVITY IN FRAME
308
STORE AN INDICATION OF ACTIVITY IN FRAME
310
STORE AN INDICATION OF A DISCREPANCY
312
NO
ACTIVITY
THRESHOLD MET?
314
YES
STORE AN INDICATION OF AN ACTIVITY WINDOW
316
GENERATE A FRAME OF IMAGE DATA
318
ANALYZING THE FRAME FOR ACTIVITY
320
ACTIVITY
IN FRAME?
322
YES
STORE AN INDICATION OF
ACTIVITY IN FRAME
324
NO
3B

FIG. 3A

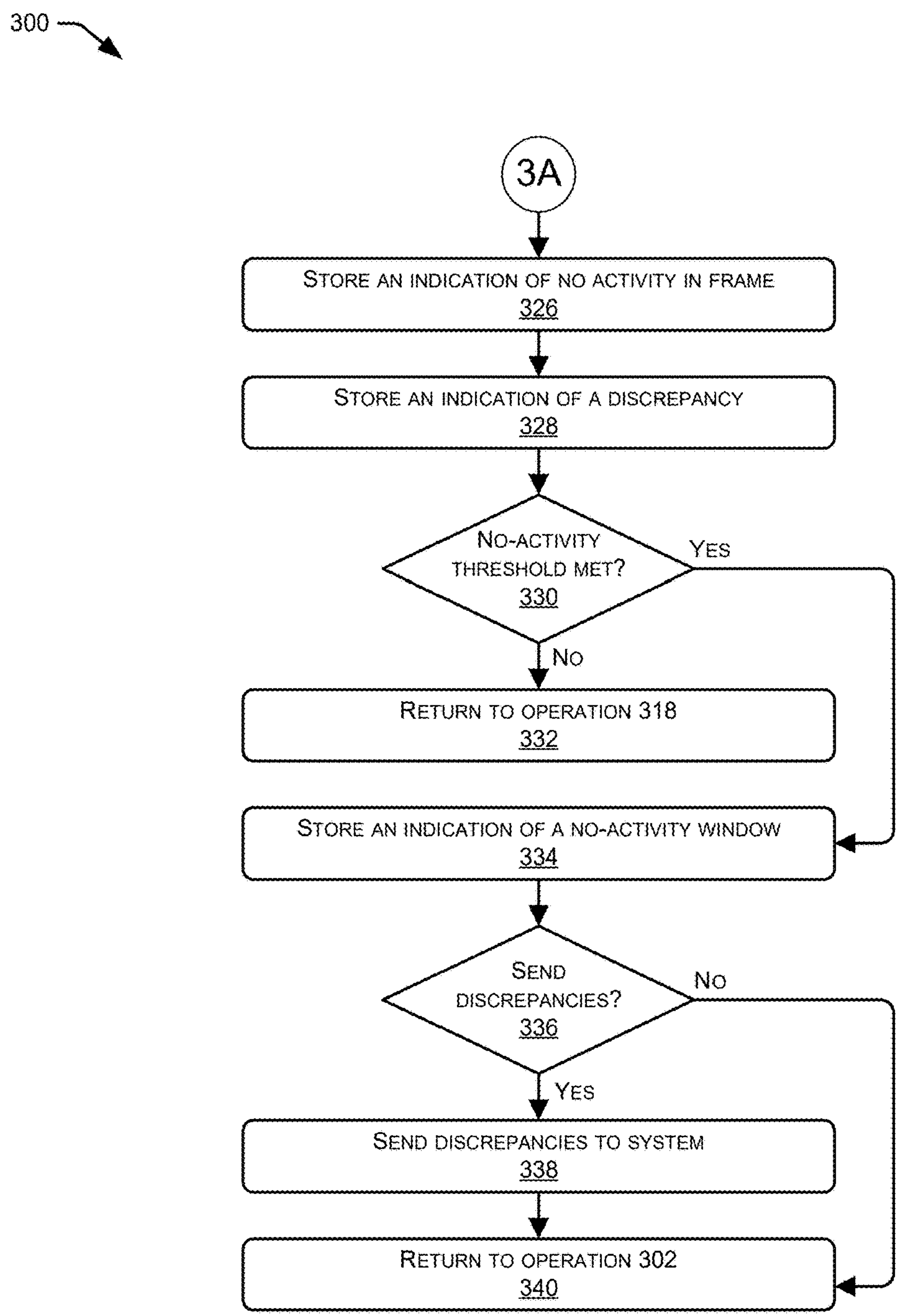

300
3A
STORE AN INDICATION OF NO ACTIVITY IN FRAME
326
STORE AN INDICATION OF A DISCREPANCY
328
NO-ACTIVITY THRESHOLD MET?
330
YES
NO
RETURN TO OPERATION 318
332
STORE AN INDICATION OF A NO-ACTIVITY WINDOW
334
SEND DISCREPANCIES?
336
NO
YES
SEND DISCREPANCIES TO SYSTEM
338
RETURN TO OPERATION 302
340

FIG. 3B

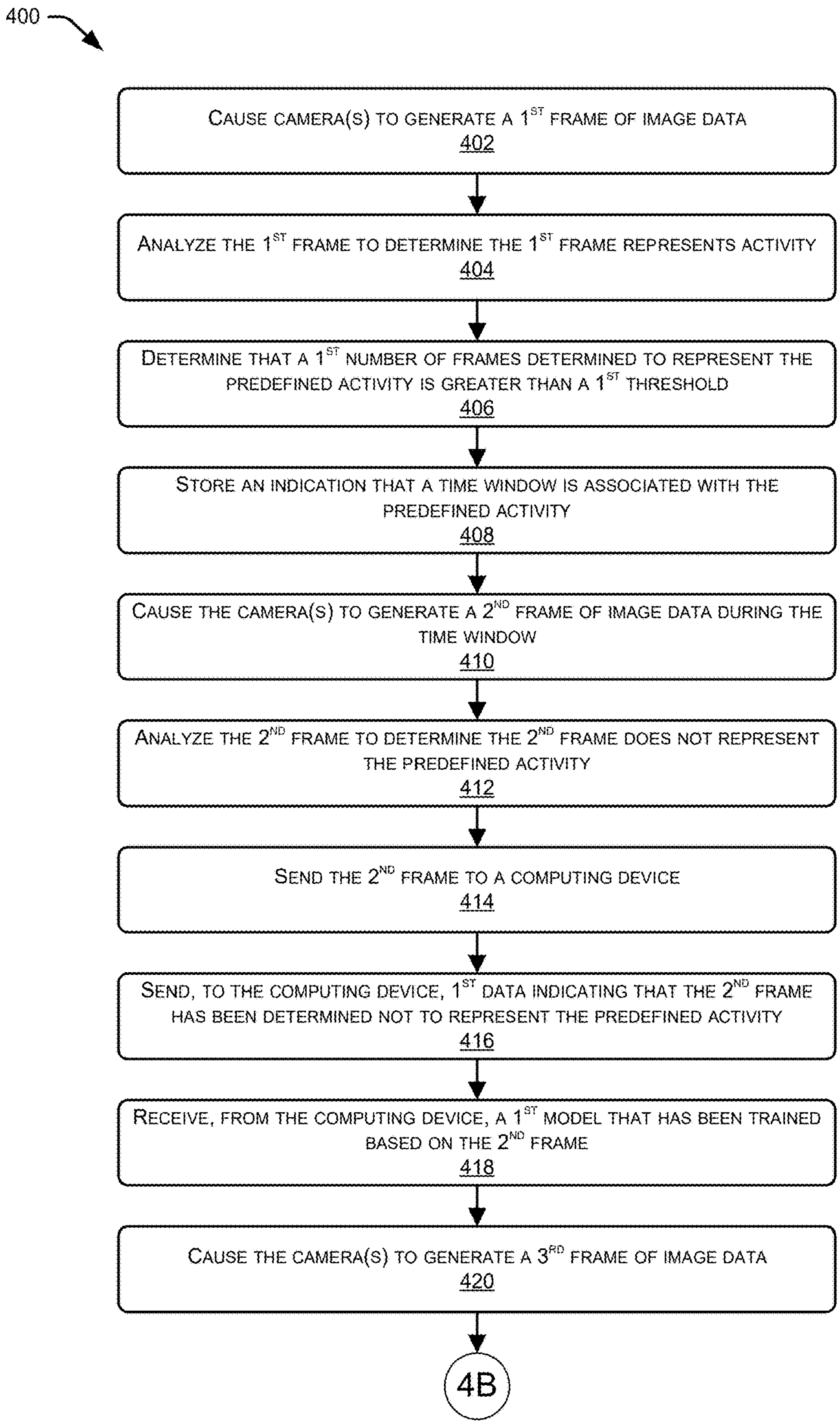

400
CAUSE CAMERA(S) TO GENERATE A 1ST FRAME OF IMAGE DATA
402
ANALYZE THE 1ST FRAME TO DETERMINE THE 1ST FRAME REPRESENTS ACTIVITY
404
DETERMINE THAT A 1ST NUMBER OF FRAMES DETERMINED TO REPRESENT THE PREDEFINED ACTIVITY IS GREATER THAN A 1ST THRESHOLD
406
STORE AN INDICATION THAT A TIME WINDOW IS ASSOCIATED WITH THE PREDEFINED ACTIVITY
408
CAUSE THE CAMERA(S) TO GENERATE A 2ND FRAME OF IMAGE DATA DURING THE TIME WINDOW
410
ANALYZE THE 2ND FRAME TO DETERMINE THE 2ND FRAME DOES NOT REPRESENT THE PREDEFINED ACTIVITY
412
SEND THE 2ND FRAME TO A COMPUTING DEVICE
414
SEND, TO THE COMPUTING DEVICE, 1ST DATA INDICATING THAT THE 2ND FRAME HAS BEEN DETERMINED NOT TO REPRESENT THE PREDEFINED ACTIVITY
416
RECEIVE, FROM THE COMPUTING DEVICE, A 1ST MODEL THAT HAS BEEN TRAINED BASED ON THE 2ND FRAME
418
CAUSE THE CAMERA(S) TO GENERATE A 3RD FRAME OF IMAGE DATA
420
4B

FIG. 4A

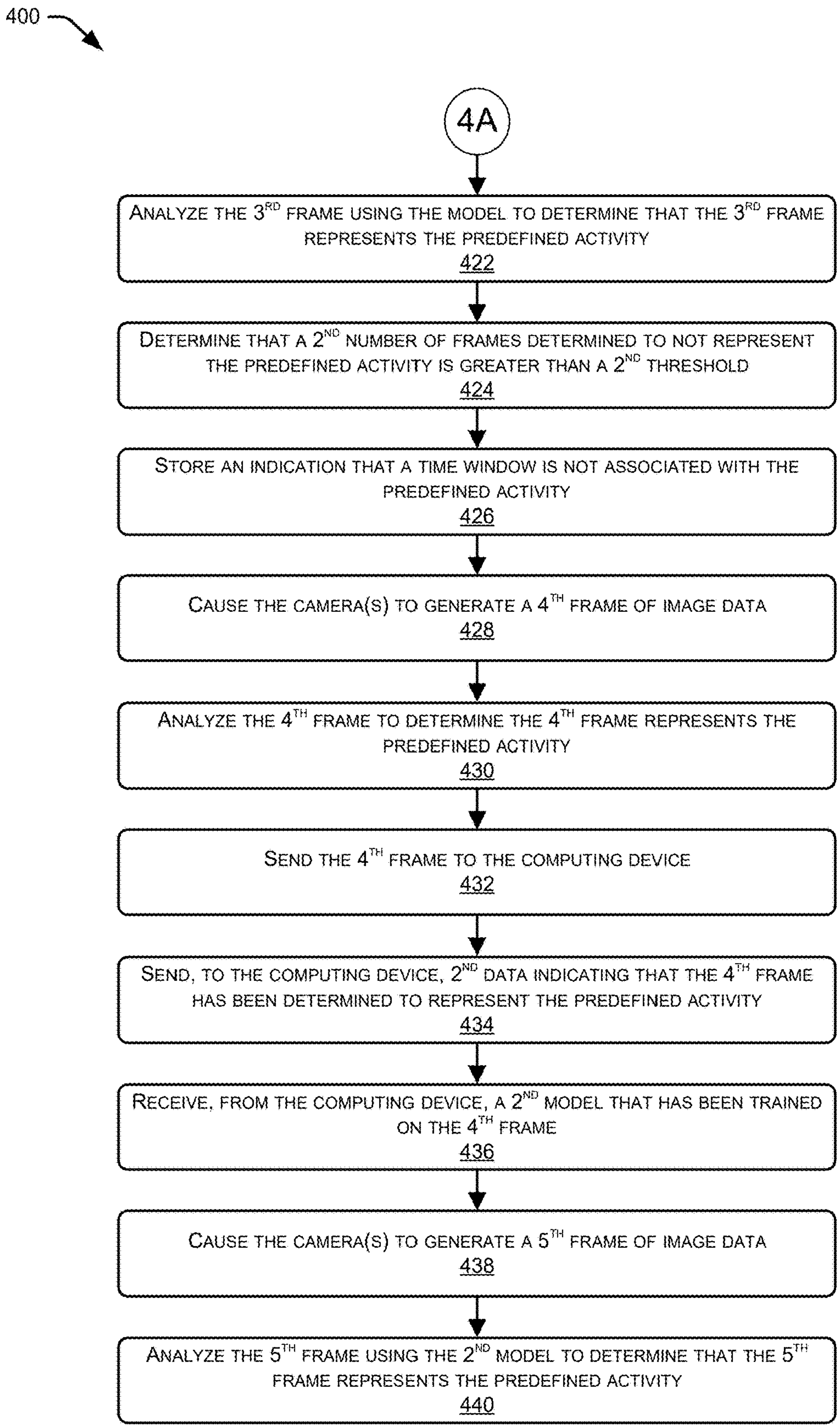

400
4A
ANALYZE THE 3^{RD} FRAME USING THE MODEL TO DETERMINE THAT THE 3^{RD} FRAME REPRESENTS THE PREDEFINED ACTIVITY 422
DETERMINE THAT A 2^{ND} NUMBER OF FRAMES DETERMINED TO NOT REPRESENT THE PREDEFINED ACTIVITY IS GREATER THAN A 2^{ND} THRESHOLD 424
STORE AN INDICATION THAT A TIME WINDOW IS NOT ASSOCIATED WITH THE PREDEFINED ACTIVITY 426
CAUSE THE CAMERA(S) TO GENERATE A 4^{TH} FRAME OF IMAGE DATA 428
ANALYZE THE 4^{TH} FRAME TO DETERMINE THE 4^{TH} FRAME REPRESENTS THE PREDEFINED ACTIVITY 430
SEND THE 4^{TH} FRAME TO THE COMPUTING DEVICE 432
SEND, TO THE COMPUTING DEVICE, 2^{ND} DATA INDICATING THAT THE 4^{TH} FRAME HAS BEEN DETERMINED TO REPRESENT THE PREDEFINED ACTIVITY 434
RECEIVE, FROM THE COMPUTING DEVICE, A 2^{ND} MODEL THAT HAS BEEN TRAINED ON THE 4^{TH} FRAME 436
CAUSE THE CAMERA(S) TO GENERATE A 5^{TH} FRAME OF IMAGE DATA 438
ANALYZE THE 5^{TH} FRAME USING THE 2^{ND} MODEL TO DETERMINE THAT THE 5^{TH} FRAME REPRESENTS THE PREDEFINED ACTIVITY 440

FIG. 4B

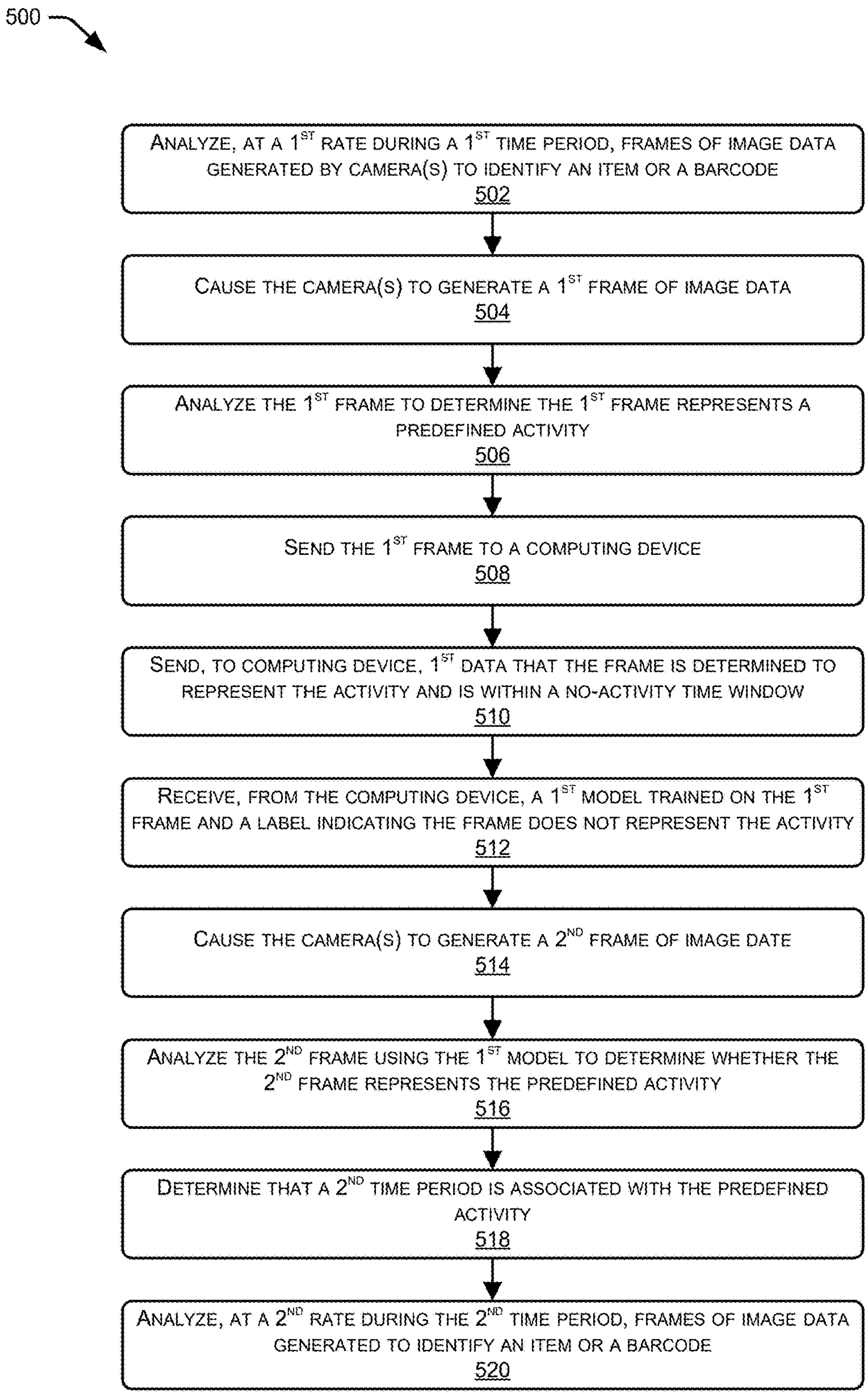

500
ANALYZE, AT A 1ST RATE DURING A 1ST TIME PERIOD, FRAMES OF IMAGE DATA GENERATED BY CAMERA(S) TO IDENTIFY AN ITEM OR A BARCODE
502
CAUSE THE CAMERA(S) TO GENERATE A 1ST FRAME OF IMAGE DATA
504
ANALYZE THE 1ST FRAME TO DETERMINE THE 1ST FRAME REPRESENTS A PREDEFINED ACTIVITY
506
SEND THE 1ST FRAME TO A COMPUTING DEVICE
508
SEND, TO COMPUTING DEVICE, 1ST DATA THAT THE FRAME IS DETERMINED TO REPRESENT THE ACTIVITY AND IS WITHIN A NO-ACTIVITY TIME WINDOW
510
RECEIVE, FROM THE COMPUTING DEVICE, A 1ST MODEL TRAINED ON THE 1ST FRAME AND A LABEL INDICATING THE FRAME DOES NOT REPRESENT THE ACTIVITY
512
CAUSE THE CAMERA(S) TO GENERATE A 2ND FRAME OF IMAGE DATE
514
ANALYZE THE 2ND FRAME USING THE 1ST MODEL TO DETERMINE WHETHER THE 2ND FRAME REPRESENTS THE PREDEFINED ACTIVITY
516
DETERMINE THAT A 2ND TIME PERIOD IS ASSOCIATED WITH THE PREDEFINED ACTIVITY
518
ANALYZE, AT A 2ND RATE DURING THE 2ND TIME PERIOD, FRAMES OF IMAGE DATA GENERATED TO IDENTIFY AN ITEM OR A BARCODE
520

FIG. 5

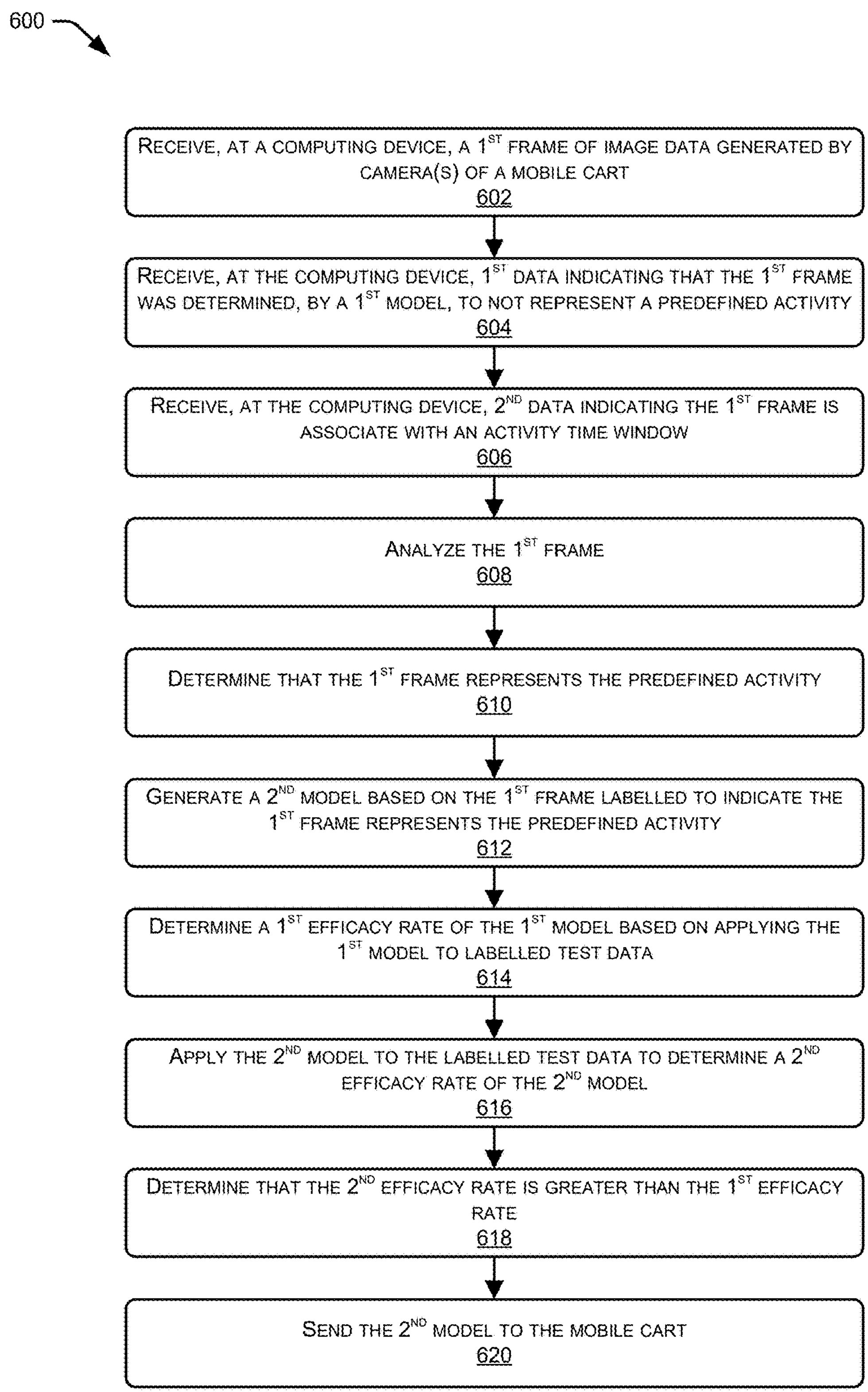

600
Receive, at a computing device, a 1^{ST} frame of image data generated by camera(s) of a mobile cart
602
Receive, at the computing device, 1^{ST} data indicating that the 1^{ST} frame was determined, by a 1^{ST} model, to not represent a predefined activity
604
Receive, at the computing device, 2^{ND} data indicating the 1^{ST} frame is associate with an activity time window
606
Analyze the 1^{ST} frame
608
Determine that the 1^{ST} frame represents the predefined activity
610
Generate a 2^{ND} model based on the 1^{ST} frame labelled to indicate the 1^{ST} frame represents the predefined activity
612
Determine a 1^{ST} efficacy rate of the 1^{ST} model based on applying the 1^{ST} model to labelled test data
614
Apply the 2^{ND} model to the labelled test data to determine a 2^{ND} efficacy rate of the 2^{ND} model
616
Determine that the 2^{ND} efficacy rate is greater than the 1^{ST} efficacy rate
618
Send the 2^{ND} model to the mobile cart
620

FIG. 6

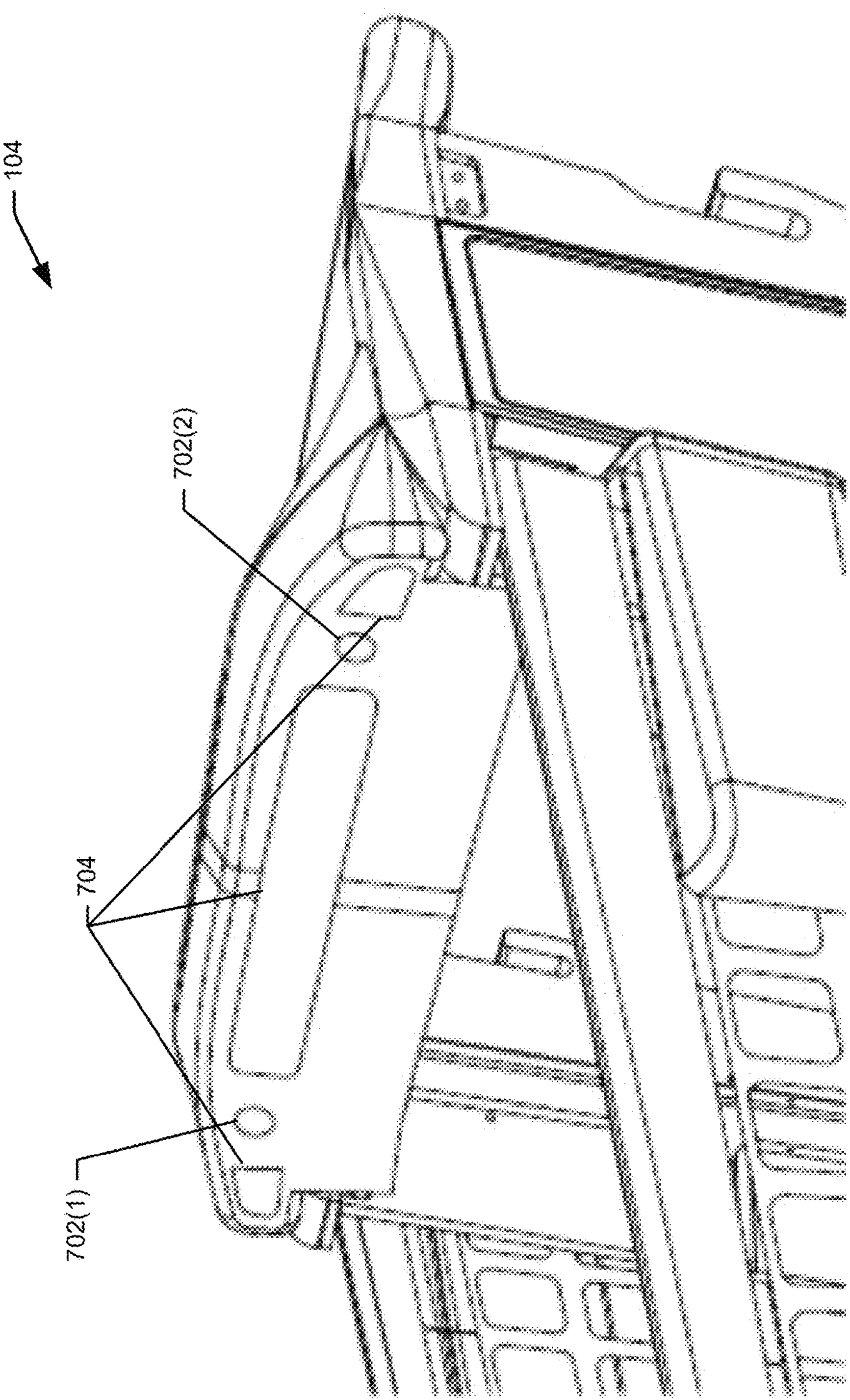


FIG. 7A

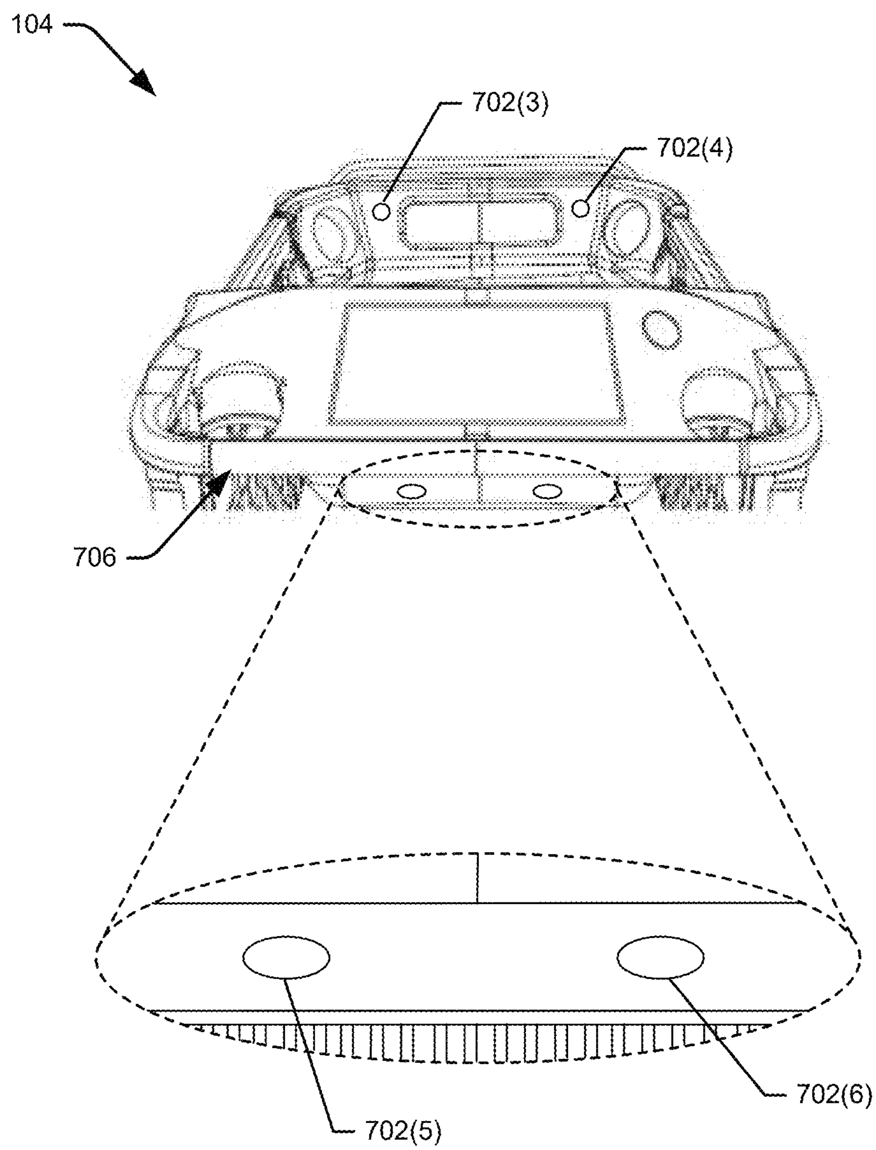
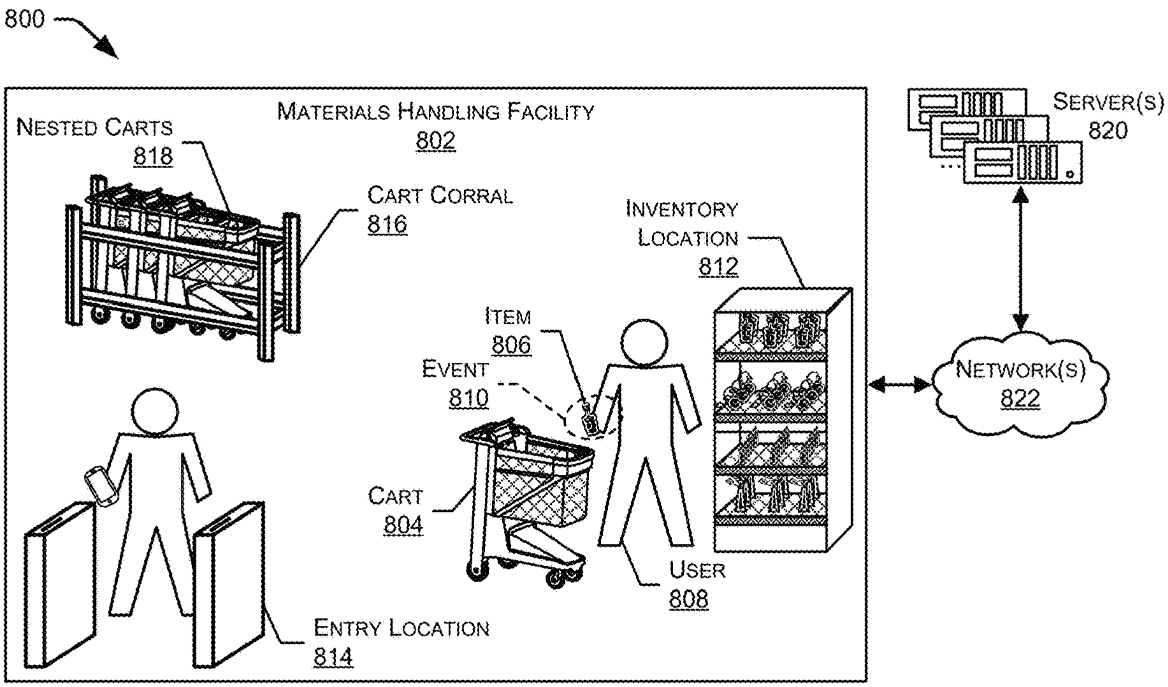


FIG. 7B


800
Materials Handling Facility
802
Nested Carts
818
Cart Corral
816
Inventory
Location
812
Item
806
Event
810
Cart
804
User
808
Entry Location
814
Server(s)
820
Network(s)
822

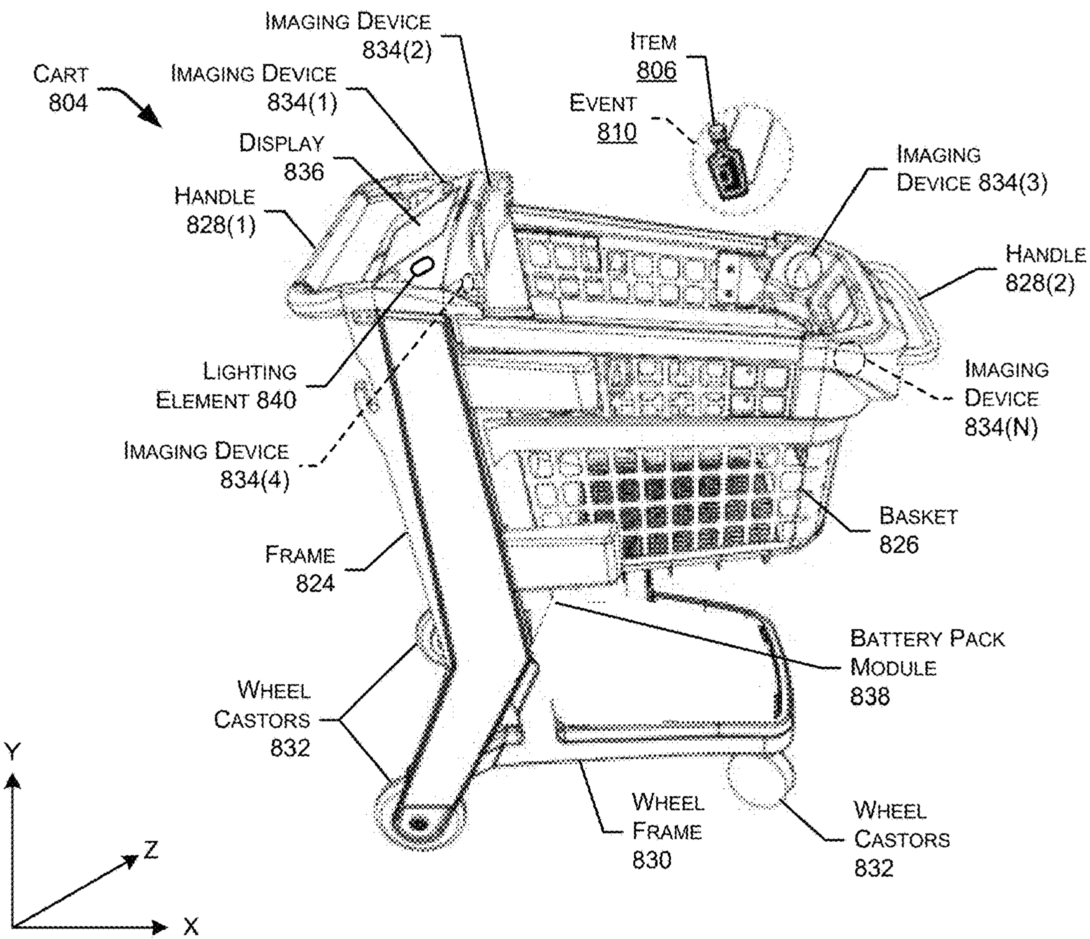

Cart
804
Imaging Device
834(2)
Imaging Device
834(1)
Display
836
Handle
828(1)
Item
806
Event
810
Imaging
Device 834(3)
Handle
828(2)
Lighting
Element 840
Imaging Device
834(4)
Imaging
Device
834(N)
Basket
826
Frame
824
Battery Pack
Module
838
Wheel
Castors
832
Wheel
Frame
830
Wheel
Castors
832
Y
Z
X

FIG. 8

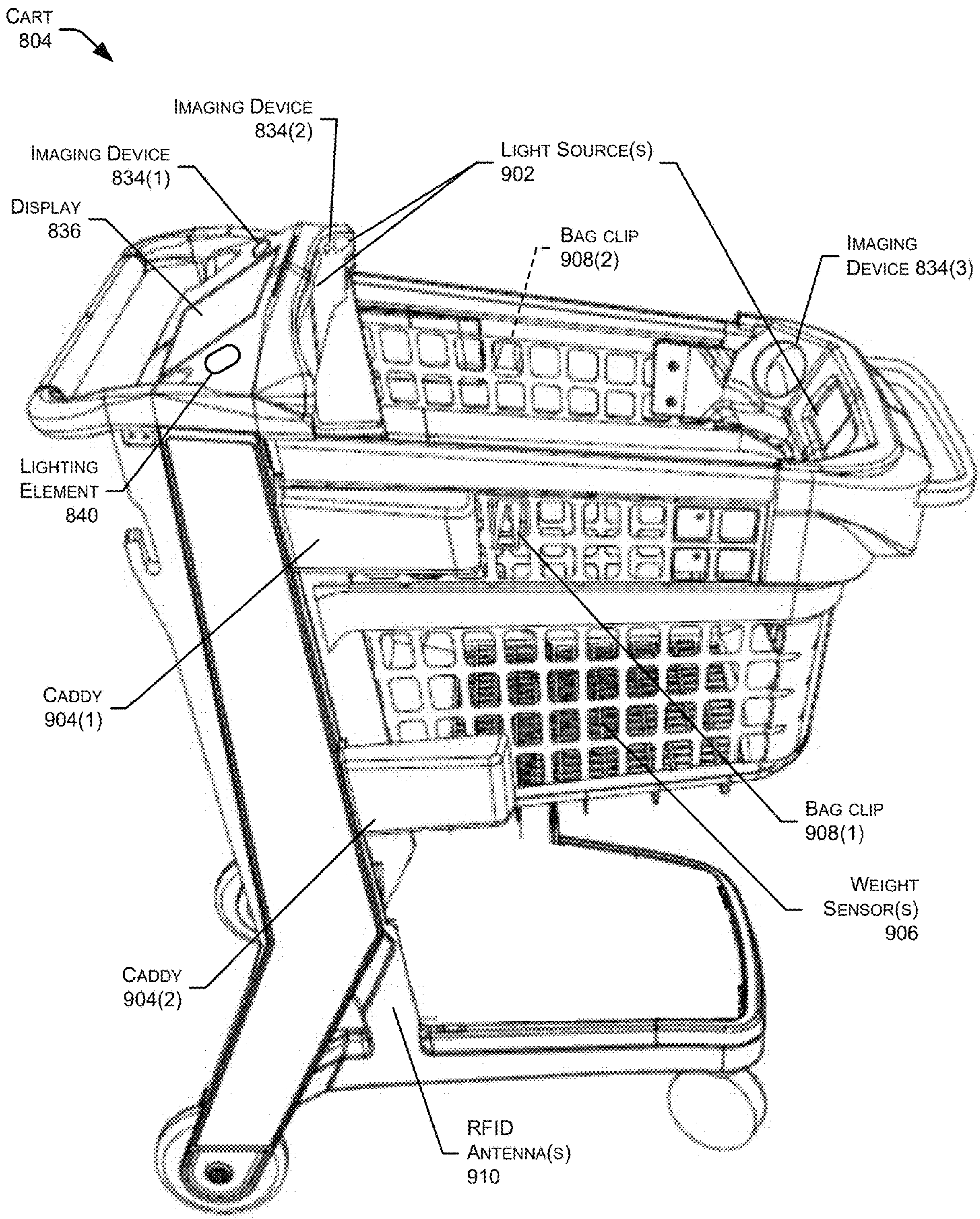

CART
804
IMAGING DEVICE
834(2)
IMAGING DEVICE
834(1)
LIGHT SOURCE(S)
902
DISPLAY
836
BAG CLIP
908(2)
IMAGING
DEVICE 834(3)
LIGHTING
ELEMENT
840
CADDY
904(1)
BAG CLIP
908(1)
WEIGHT
SENSOR(S)
906
CADDY
904(2)
RFID
ANTENNA(S)
910

FIG. 9

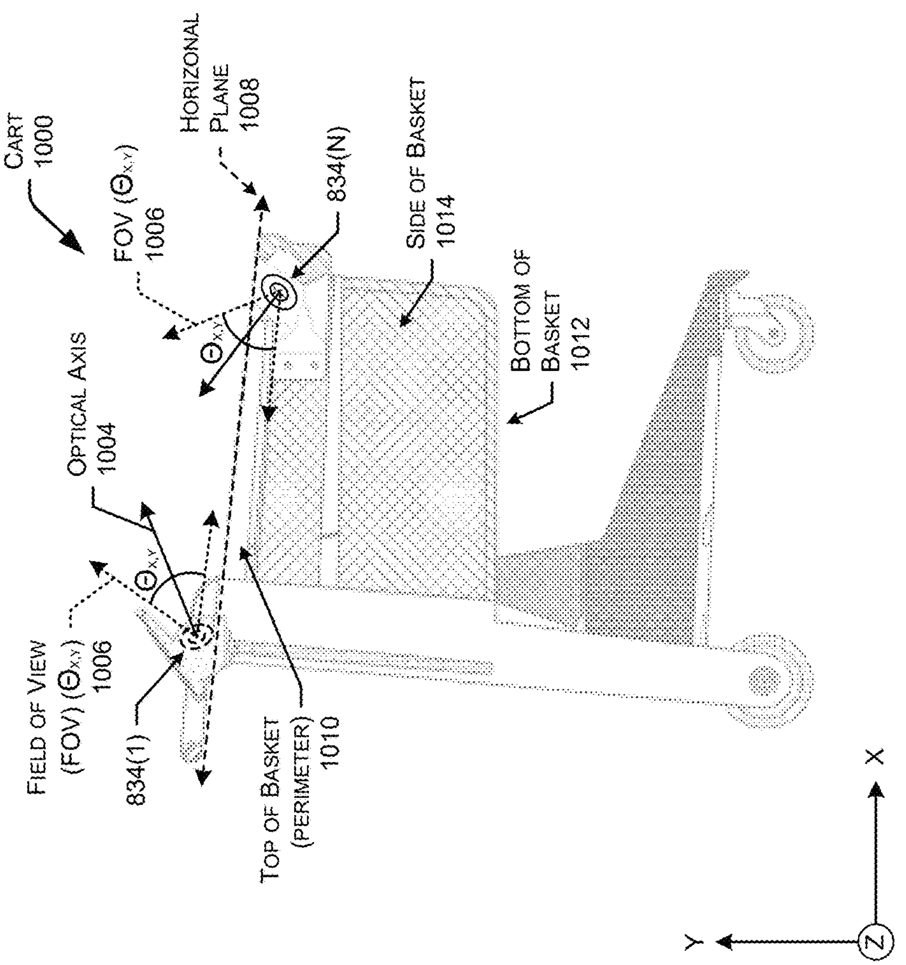


FIG. 10A

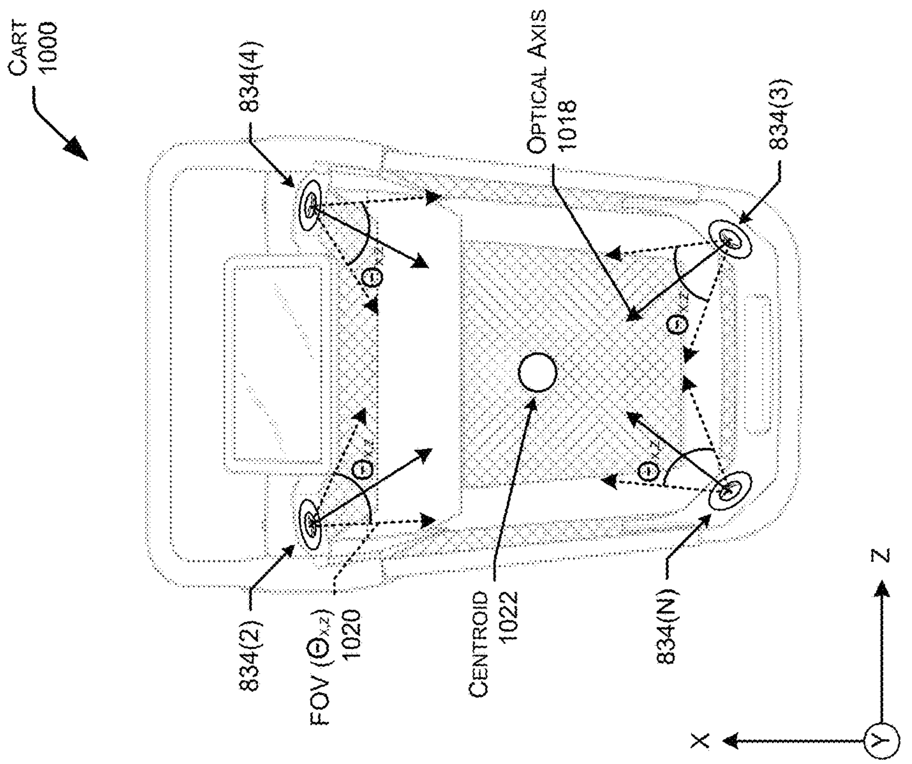


FIG. 10B

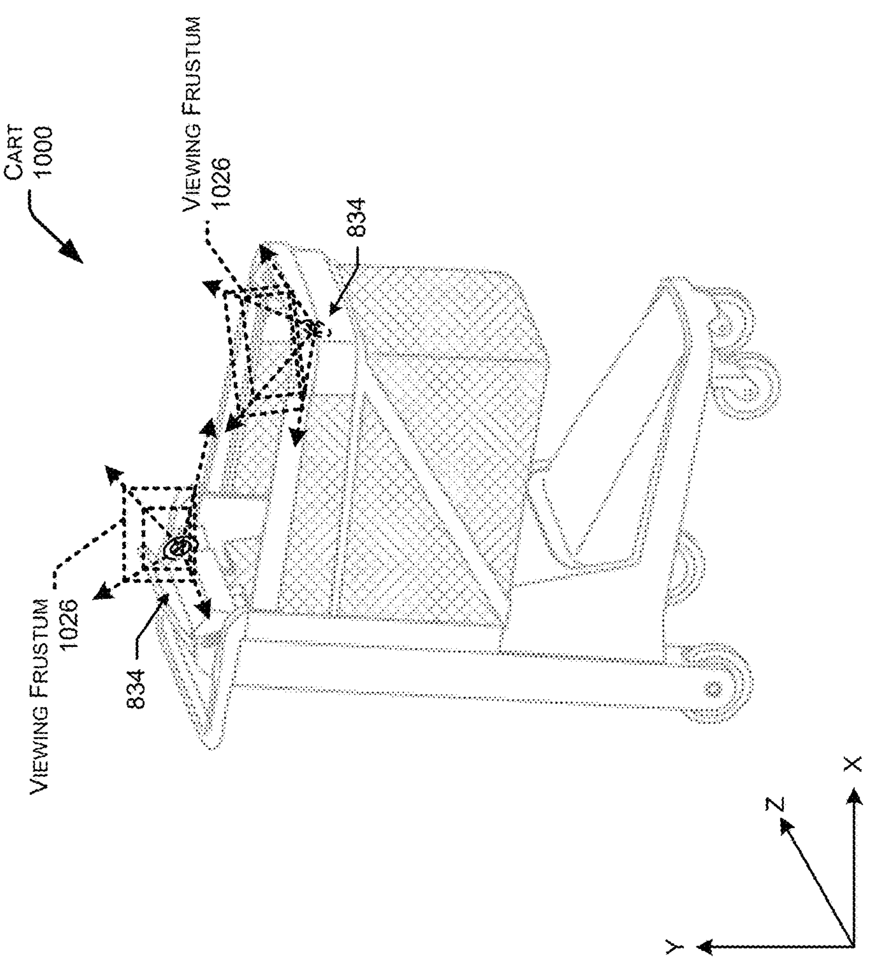


FIG. 10C

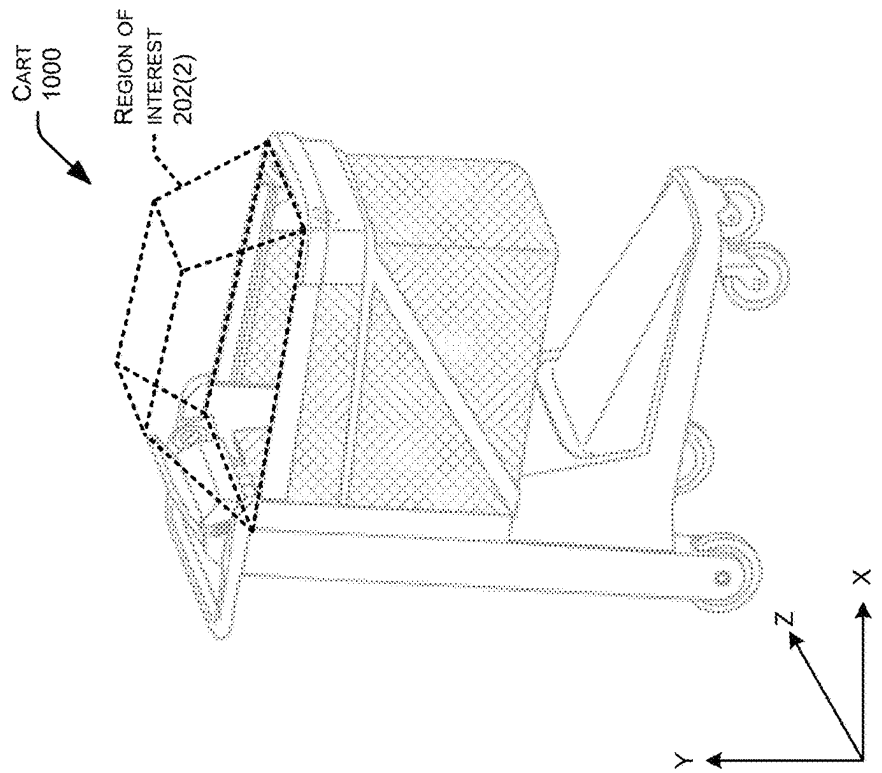


FIG. 10D

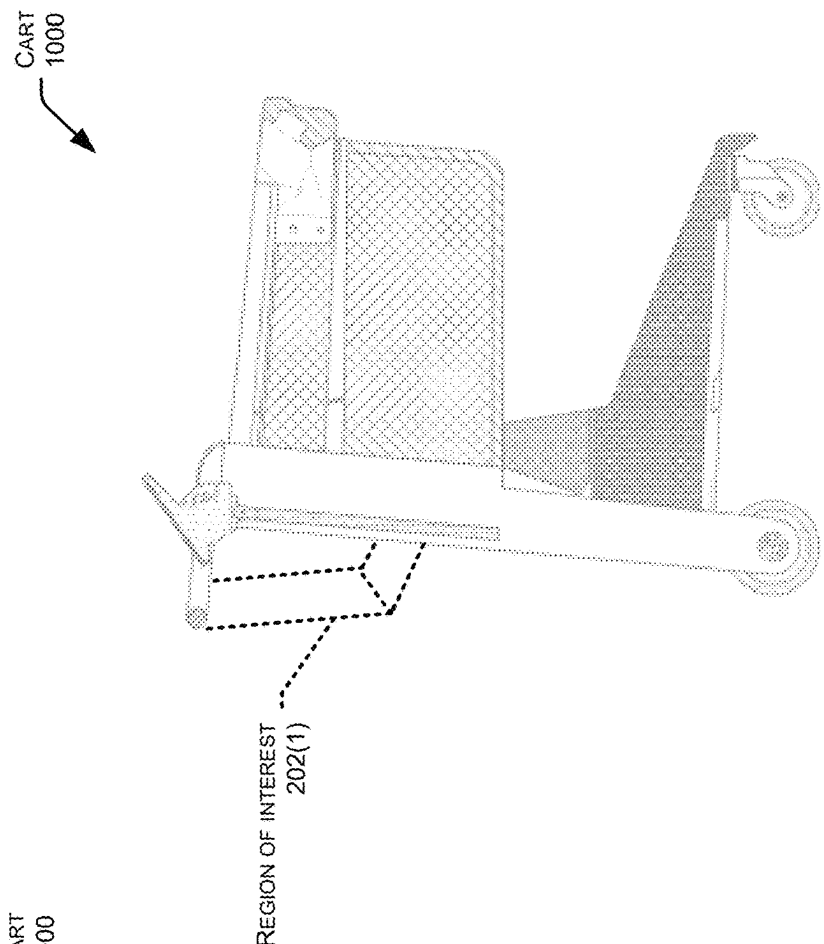


FIG. 11B

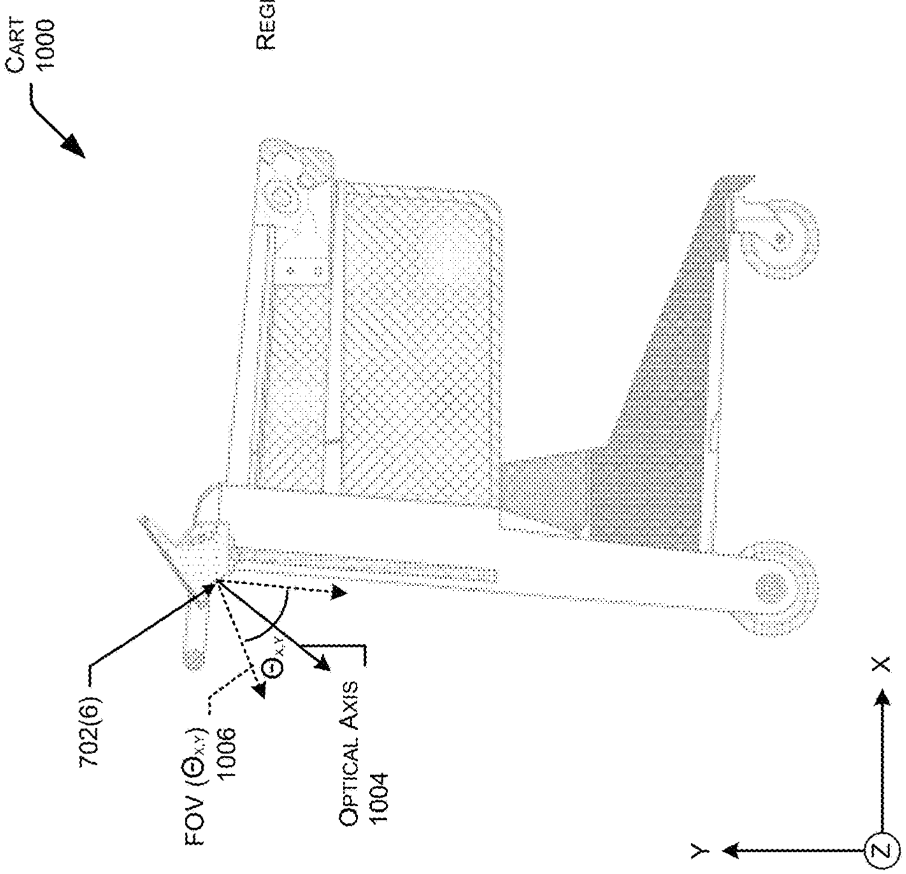
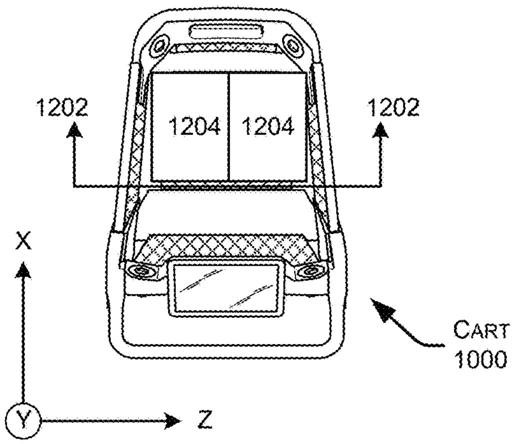


FIG. 11A


1202
1204
1204
1202
X
CART
1000
Y
Z

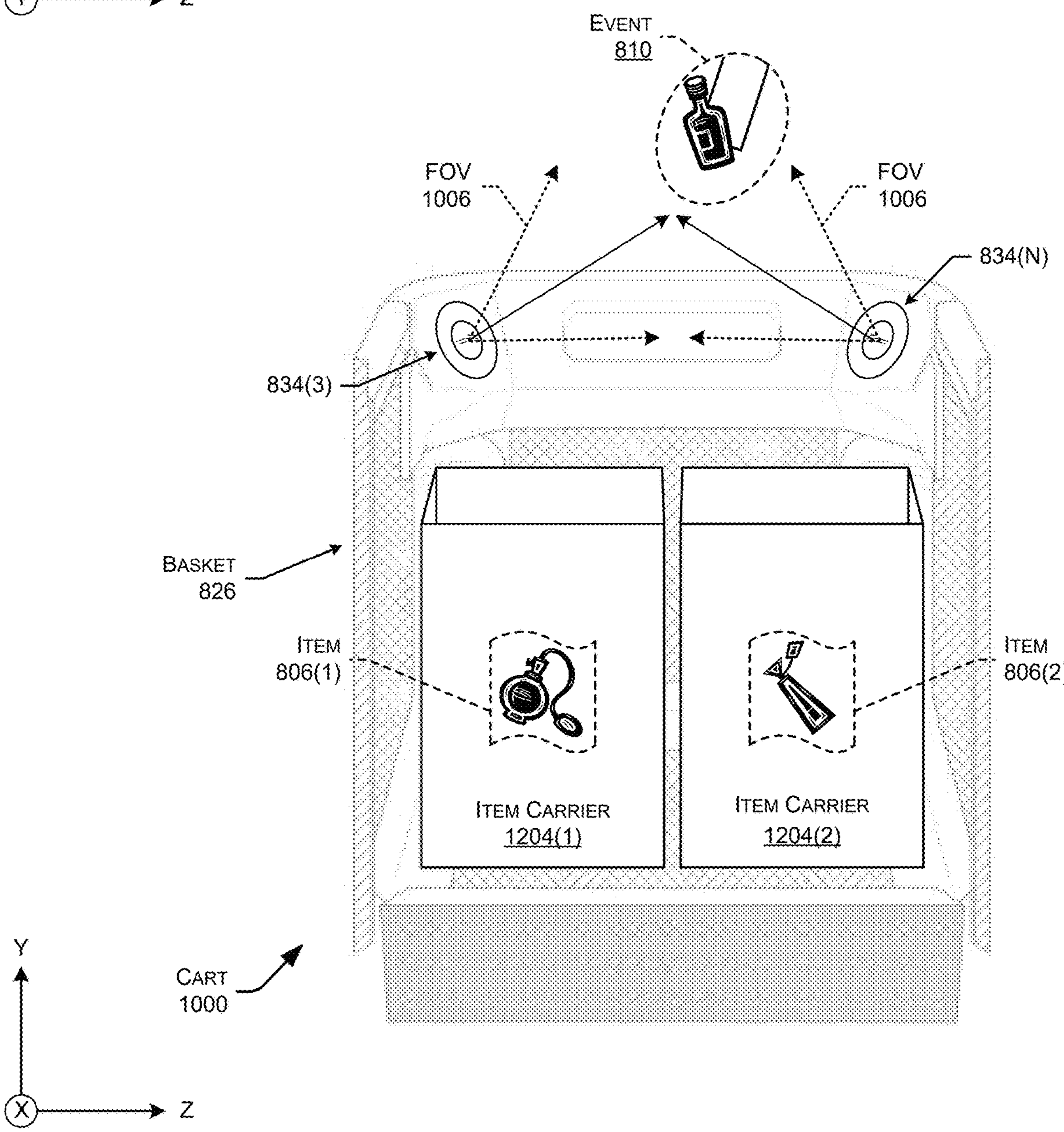

EVENT
810
FOV
1006
FOV
1006
834(N)
834(3)
BASKET
826
ITEM
806(1)
ITEM
806(2)
ITEM CARRIER
1204(1)
ITEM CARRIER
1204(2)
CART
1000
Y
X
Z

FIG. 12

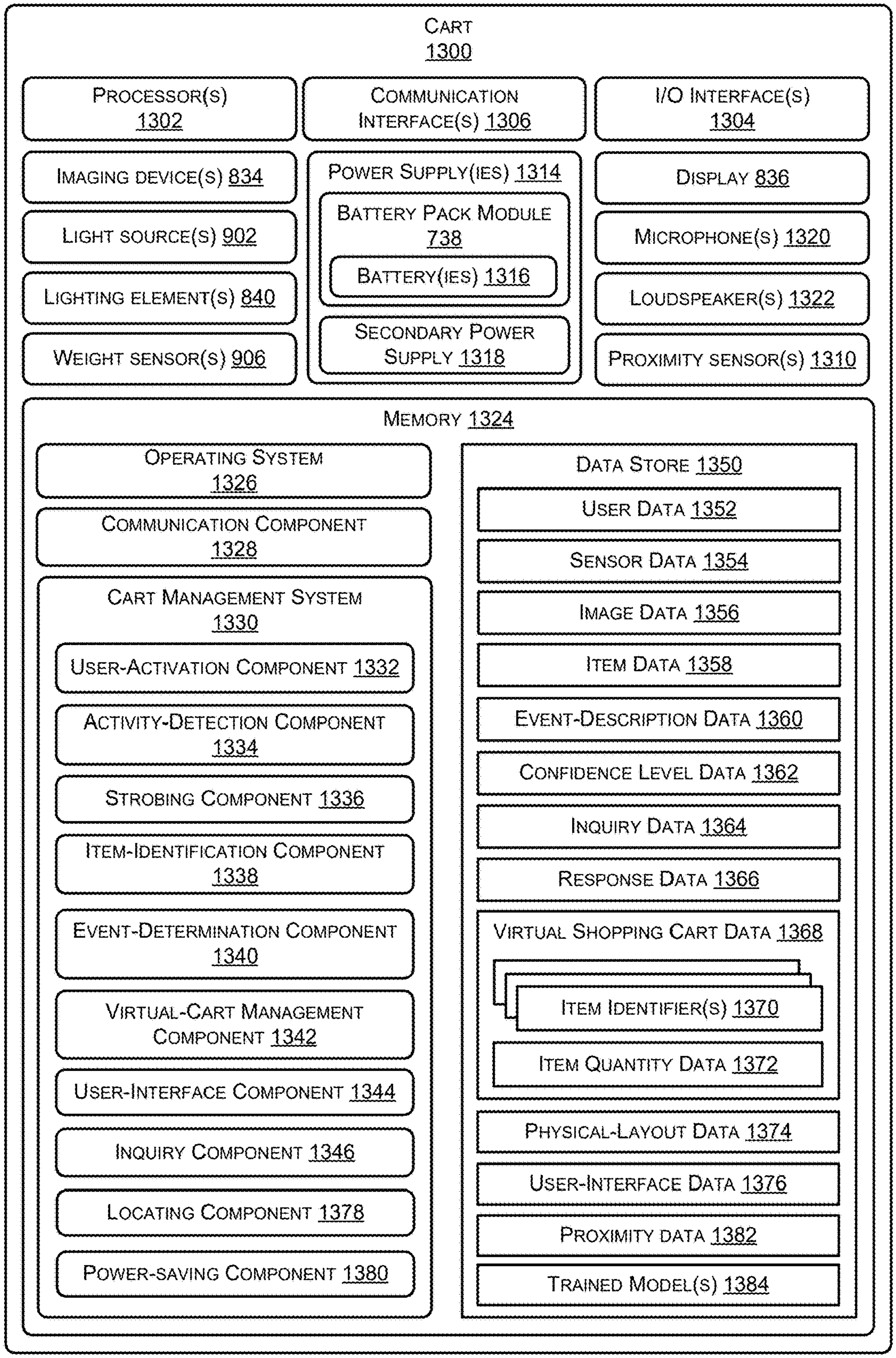

CART 1300
PROCESSOR(S) 1302
COMMUNICATION INTERFACE(S) 1306
I/O INTERFACE(S) 1304
IMAGING DEVICE(S) 834
LIGHT SOURCE(S) 902
LIGHTING ELEMENT(S) 840
WEIGHT SENSOR(S) 906
POWER SUPPLY(IES) 1314
BATTERY PACK MODULE 738
BATTERY(IES) 1316
SECONDARY POWER SUPPLY 1318
DISPLAY 836
MICROPHONE(S) 1320
LOUDSPEAKER(S) 1322
PROXIMITY SENSOR(S) 1310
MEMORY 1324
OPERATING SYSTEM 1326
COMMUNICATION COMPONENT 1328
CART MANAGEMENT SYSTEM 1330
USER-ACTIVATION COMPONENT 1332
ACTIVITY-DETECTION COMPONENT 1334
STROBING COMPONENT 1336
ITEM-IDENTIFICATION COMPONENT 1338
EVENT-DETERMINATION COMPONENT 1340
VIRTUAL-CART MANAGEMENT COMPONENT 1342
USER-INTERFACE COMPONENT 1344
INQUIRY COMPONENT 1346
LOCATING COMPONENT 1378
POWER-SAVING COMPONENT 1380
DATA STORE 1350
USER DATA 1352
SENSOR DATA 1354
IMAGE DATA 1356
ITEM DATA 1358
EVENT-DESCRIPTION DATA 1360
CONFIDENCE LEVEL DATA 1362
INQUIRY DATA 1364
RESPONSE DATA 1366
VIRTUAL SHOPPING CART DATA 1368
ITEM IDENTIFIER(S) 1370
ITEM QUANTITY DATA 1372
PHYSICAL-LAYOUT DATA 1374
USER-INTERFACE DATA 1376
PROXIMITY DATA 1382
TRAINED MODEL(S) 1384

FIG. 13

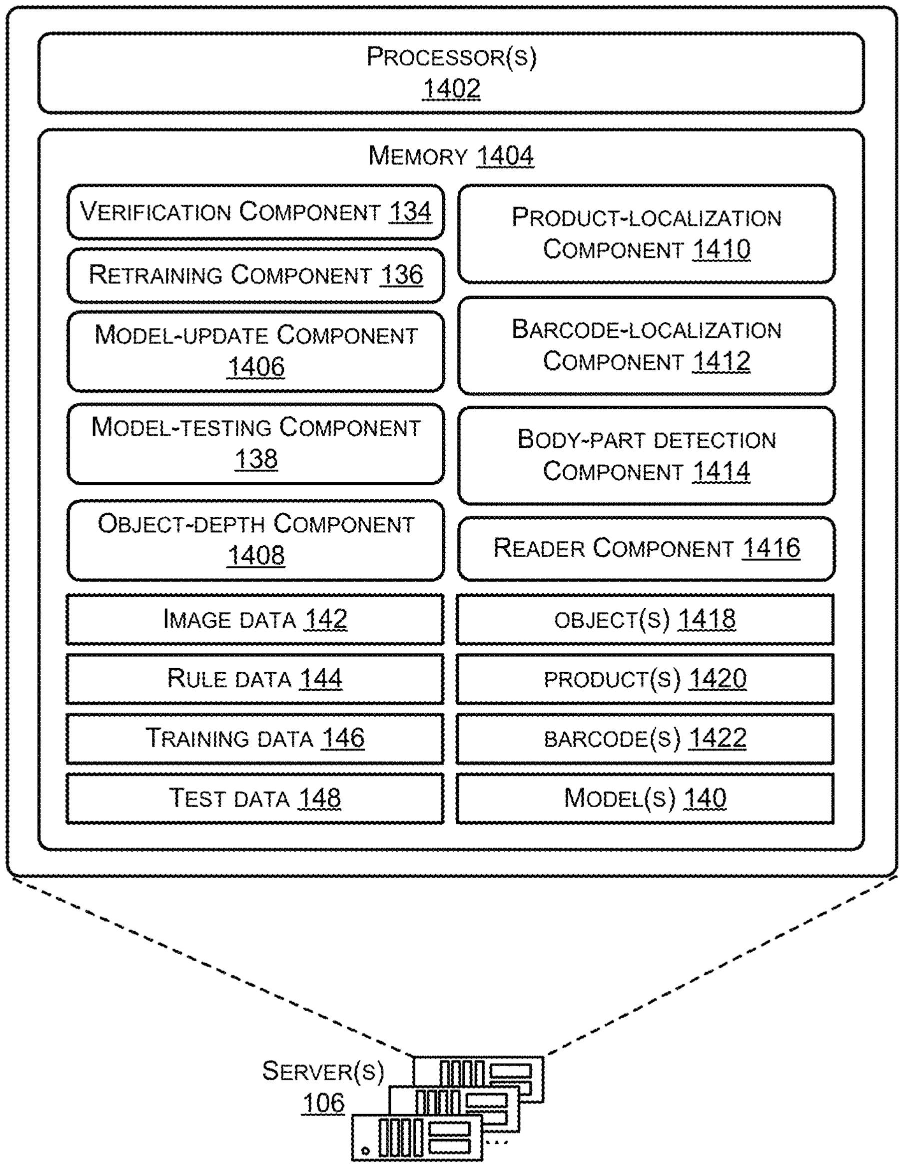

PROCESSOR(S)
1402
MEMORY 1404
VERIFICATION COMPONENT 134
RETRAINING COMPONENT 136
MODEL-UPDATE COMPONENT 1406
MODEL-TESTING COMPONENT 138
OBJECT-DEPTH COMPONENT 1408
PRODUCT-LOCALIZATION COMPONENT 1410
BARCODE-LOCALIZATION COMPONENT 1412
BODY-PART DETECTION COMPONENT 1414
READER COMPONENT 1416
IMAGE DATA 142
RULE DATA 144
TRAINING DATA 146
TEST DATA 148
OBJECT(S) 1418
PRODUCT(S) 1420
BARCODE(S) 1422
MODEL(S) 140
SERVER(S)
106

FIG. 14

CONSERVING POWER IN ITEM-IDENTIFYING CARTS

BACKGROUND

Materials handling facilities, such as warehouses or retail stores, often provide users with carts to facilitate the processes by which the users locate, identify, retrieve, and transport items at the facilities. For example, when a user identifies an item that he or she desires on a shelf or other location within a materials handling facility, the user may remove the item from the shelf or other location, and place the item into a receptacle of a cart before the user continues to travel through the facility in search of additional items. The cart may have a durable frame or structure that is configured to travel on wheels such that users are able to fill the carts with numerous, and potentially heavy, items they desire, and use the mobile cart to transport the items around the materials handling facilitate with ease, rather than having to carry the items.

Traditionally, when the user has finished identifying and retrieving the items he or she desires, the user may transport the items in the cart to a check-out destination within the materials handling facility, such as a distribution station, a cashier, or a dedicated self-checkout stand, and transition the items to a human operator or an automated agent. Typically, the user or the human operator manually removes the items from the cart, scans or otherwise registers the items with the user, and places the items into one or more bags or other item carriers. The user may then use the bags or other item carriers to transport the items to another destination (e.g., to an automobile, workstation, or home) by manually carrying the item carriers to the other destination, or by transporting the item carriers to the destination within the cart.

Thus, retrieving items from shelves or other locations within a materials handling facility, and placing the items into bags or other carriers for transportation to their desired destination (e.g., automobile or home), may be a two-step process. First, the items must be retrieved from the shelves or other storage locations and placed into the cart, and second, the items must be removed from the cart, scanned, and placed into a bag or other item carrier. These intervening actions that are required to transition items from a shelf or other storage location into the bags or other item carrier necessarily slows the process by which items are retrieved from a materials handling facility, and tend to mitigate the advantages that carts provide.

BRIEF DESCRIPTION OF FIGURES

The detailed description is set forth with reference to the accompanying figures. In the figures, the left-most digit(s) of a reference number identifies the figure in which the reference number first appears. The use of the same reference numbers in different figures indicates similar or identical items or features.

FIG. **1** illustrates an example architecture that includes a user operating a mobile cart within a facility, as well as one or more server computing devices communicatively coupled to the mobile cart or other devices within the facility. As illustrated, the mobile cart may include cameras to generate image data, as well as an activity-detection component using a trained model to determine when there is activity in or near the cart. Upon detecting activity, the mobile cart may begin analyzing or may increase a rate at which the cart analyzes the image data to identify items placed into or removed from the mobile cart. In some instances, the mobile cart identifies frames that may have been misidentified as representing activity or not representing activity and may send these frames to the servers, which may use this data to update the trained model used by the cart for detecting activity.

FIG. **2**A illustrates an example schematic diagram of a mobile cart analyzing frames of image of data to detect activity and, upon identifying a threshold amount of frames that represent activity, determine an activity window. In addition, this diagram illustrates the mobile cart identifying frames where a model utilized by the mobile cart may have misidentified a frame that includes activity as not representing activity. The mobile cart may store this frame and associated information for later use in re-training the model to improve the accuracy of the model.

FIG. **2**B illustrates an example schematic diagram of a mobile cart analyzing frames of image of data to detect activity and, upon identifying a threshold amount of frames that do not represent activity, determine a no-activity window. In addition, this diagram illustrates the mobile cart identifying frames where a model utilized by the mobile cart may have misidentified a frame that does not include activity as representing activity. The mobile cart may store this frame and associated information for later use in re-training the model to improve the accuracy of the model.

FIGS. **3**A-B collectively illustrate a flow diagram of an example process for analyzing frames of image data to detect activity, as well as identify discrepancies where a trained model utilized to analyze the image data may have incorrectly identified a frame as representing activity or not representing activity.

FIGS. **4**A-B collectively illustrate a flow diagram of another example process for analyzing frames of image data to detect activity, as well as identify discrepancies where a trained model utilized to analyze the image data may have incorrectly identified a frame as not representing activity.

FIG. **5** illustrates a flow diagram of another example process for analyzing frames of image data to detect activity, as well as identify discrepancies where a trained model utilized to analyze the image data may have incorrectly identified a frame as representing activity.

FIG. **6** illustrates a flow diagram of an example process for using new training data generated from misidentified frames to generate an updated model to more accurately identify activity proximate a mobile cart or otherwise.

FIG. **7**A illustrates an example mobile cart that includes cameras pointed toward a basket of the cart for generating image data that may be used to determine when a user is placing an item into or removing an item from the basket, as well as to identify the item and a quantity of the item.

FIG. **7**B illustrates an example mobile cart that includes additional cameras directed towards the basket, as well as cameras directed toward a handle of the cart for generating image data that may be used to determine when a user is placing an item into or removing an item from a storage location of the cart located under the handle area, as well as to identify the item and a quantity of the item.

FIG. **8** illustrates an example environment of a materials handling facility that includes an item-identifying cart to identify items placed in, and removed from, a basket of the cart by a user. The cart may identify a user operating the cart, may identify items placed into the cart, and may update a virtual shopping cart associated with the user to indicate the items added to the cart.

FIG. **9** illustrates the example cart of FIG. **8** in further detail.

FIGS. **10**A-D illustrate example views of an item-identifying cart that has one or more cameras for identifying items placed in the cart. In addition, FIG. **10**D illustrates a region of interest near the basket that components of the cart may analyze when attempting to identify items placed into or removed from the basket of the cart.

FIGS. **11**A-B illustrate example views of an item-identifying cart that has one or more cameras for identifying items placed in a storage location of the cart that is located beneath the handle and the basket. In addition, FIG. **11**B illustrates a region of interest near the storage location that components of the cart may analyze when attempting to identify items placed into or removed from this storage location.

FIG. **12** illustrates another example cross-sectional view of an item-identifying cart that has item carriers placed inside the basket of the cart, and cameras that are used to identify an item being placed in the item carriers.

FIG. **13** illustrates example components of an item-identifying cart configured to support at least a portion of the functionality of a cart management system.

FIG. **14** illustrates example components of server computing devices for generate models for use by mobile carts to detect activity represented by image data generated by cameras of the respective mobile carts.

DETAILED DESCRIPTION

This disclosure is directed to item-identifying carts that may be utilized by users in material handling facilities to automatically identify items that the users place in their carts as they move around the material handling facilities, as well as to identify the users operating the carts. Upon identifying a user operating a cart and items placed into the cart, the item-identifying cart may update a virtual shopping cart of the user to represent the items that have been placed in, or removed from, the physical cart. According to the techniques described herein, an item-identifying cart (or "smart cart") may include one or more first cameras positioned on a frame of the cart and directed substantially toward a position typically occupied by a user pushing the cart to generate first image data for identifying the user as well as for identifying items placed into a storage location underneath the handle and adjacent or underneath a basket of the cart. For example, the first image data may represent an identifier associated with an account of the user displayed on a mobile device of the user (e.g., a barcode or the like displayed on a mobile phone), facial-recognition data representing the user, gesture data representing the user, and/or the like. The cart may include components for associating the first image data with the user, or the cart may send the first image data to one or more remote servers for determining this association.

In addition, the cart may include one or more second cameras positioned on the frame of the cart to generate second image data representing items that a user places in the cart, and/or removes from the cart. The cart may include one or more components that analyze the image data to determine an item identifier for the item(s) placed in the cart, or removed from the cart, and update a virtual shopping cart for the user of the cart. Once a user has finished their shopping session, the user may be able to efficiently check-out of the materials handling facility (or "facility") without having to scan or otherwise register their items with a cashier or at a designated self-checkout stand. In some examples, the user may simply depart the facility with their items and entirely avoid a traditional checkout experience of a facility, such as a grocery store. For instance, the user may have registered for a user account with the facility that is automatically charged for purchases of the items listed in a virtual shopping cart of the user that were identified by the cart during the user's shopping session.

Similar to traditional carts, such as shopping carts commonly found at grocery stores or other retail establishments, the item-identifying carts described herein may include a durable frame, including or supporting a basket, made of plastic or metal (often having four sides in a quadrilateral shape), multiple wheel castors configured to allow the cart to move on a surface, and one or more handles for a user to push and/or pull the cart around in a facility. However, the carts described herein may include additional hardware and software components that configure the carts to, among other functions, identify items placed in the carts on behalf of the users, and update virtual carts of the users to automate one or more steps of a traditional shopping experience.

For example, an item-identifying cart may include one or more cameras (or other imaging sensors), memory that stores software components for identifying users and/or items and for performing other operations for managing virtual shopping carts, at least one processor to execute the software components, and at least one battery to power the components of the cart. The camera(s) may include one or more first cameras positioned on the frame toward a location where a user would typically push the cart. The one or more first cameras may generate first image data, such as image data of a mobile phone of a user representing visual indicia (e.g., a barcode) associated with an account of the user. Thus, the user may hold up his or her mobile device representing the visual indicia such that the first camera(s) may scan or otherwise generate the first image data. The cart may then identify the account of the user using the first image data or may send the image data to a remote server(s), which may identify the user account using the first image data. Thus, items placed into the cart during a shopping session of the user operating the cart may thereafter be associated with the user account. These first cameras, or other cameras, may also be used to identify items placed into a removed from a storage location underneath the handle of the cart and adjacent to the basket of the cart.

The smart cart may further include one or more second cameras positioned on the frame of the cart such that an optical axis of the second camera(s) is directed towards a location where second image data generated by the second camera(s) represents or captures items that are placed in the cart, and removed from the cart, by a user. Both the second image data generated by the basket-facing cameras and the first image data generated by the handle-facing cameras may be analyzed by the software component(s) of the cart, and/or by remote server(s), using one or more image processing techniques, such as text recognition, object recognition, and/or any other technique. The software component(s) may identify or determine item identifiers for the items represented in the image data, and also determine whether the user is adding items to the cart, or removing items from the cart, and update a virtual shopping cart for the user's shopping session (e.g., add an item to a list of items to be purchased by the user, or remove an item from the list of items to be purchased). In this way, the cart may identify and track items that are retrieved from different locations within the facility, and maintain a virtual shopping cart, or virtual list, of the items selected by the user to provide a more seamless and efficient checkout experience for the user.

In some instances, the smart cart may also include one or more displays, which in some instances may reside adjacent the first camera(s) such that the display is viewable by the user operating the cart. The display may present content that is customized for the user at least partly in response to the cart identifying the user via the first image data. For example, upon the cart or the remote server(s) identifying the user operating the cart, the display may present information associated with the user, such as a shopping list of the user, a name of the user, account information associated with the account of the user, and/or the like. Furthermore, in some instances the display may present location-specific information. For example, if the cart determines that it is located in a particular location of a store, such as near a produce section, the display may present information regarding the particular location, such as cost of produce items near the cart. In another example, the display may present information such as promotions occurring on items that reside adjacent the location of the cart. In some instances, the presented promotions may also be determine based on information associated with the user (e.g., a past purchase history, preferences, etc.), current contents of the cart, and/or the like.

In some examples, the cart may have a frame that includes, or supports, a basket comprising a bottom having quadrilateral shape, one or more (e.g., four) sides protruding from the bottom to define an interior cavity, and a top having a perimeter that defines an opening to receive items placed in the interior cavity of the basket. One or more second cameras may be positioned on the basket of the cart to generate image data representing the items placed in the cart. In some examples, the cameras may be included in respective capture assemblies that include other components, such as light sources (e.g., light emitting diodes (LEDs)) to active and emit light on the items such that the items are illuminated in the image data to help improve processing of the image data to identify the items. In other instances, the cameras may reside adjacent the light sources.

Although the cameras may be positioned anywhere on the cart, in some examples, the basket of the cart may have cameras disposed proximate to each of the four corners of the perimeter of the top of the basket. In this way, the entire cart may be represented in the various field-of-views (FOVs) of the cameras, which also may not be obstructed as the basket of the cart fills up with items. The cameras may, in some examples, be internal to the basket, or otherwise define a relatively small protrusion from the form-factor of the basket, such that the carts may still be capable of "nesting" together in a line when stored at a facility, similar to traditional shopping carts.

Due to the battery life constraints of the cart, it may be advantageous to refrain from having the cameras and/or light sources operating for large periods of time to detect an image being placed in the cart. Thus, in some examples the cart may additionally include one or more proximity sensors (e.g., time-of-flight (ToF) sensors, passive infrared (PIR) sensors, etc.) that generate sensor data to detect movement of an item in, or out, of the cart while the cameras and light sources are de-activated or in a low-power state. In this way, proximity sensors, which may consume less power than the cameras and/or light sources, may detect movement proximate the cart before the cameras and/or light sources are activated.

Thus, the cart described herein may include four cameras disposed at or proximate to the four corners of the perimeter of the basket of the cart. To detect items placed in the cart, or removed from the cart, the cameras may have respective optical axes (e.g., imaginary line along which light propagates through the capture assembly) that are oriented towards an interior of the perimeter of the top of the cart (e.g., towards the middle or centroid of the perimeter of the cart). By orienting the cameras inward with respect to the perimeter of the top of the cart, only items that pass through (e.g., in or out) of the opening of the basket may be represented in image data of the cameras.

The cameras may additionally be oriented to face in a particular vertical direction. For instance, the optical axes of the cameras may, in some examples, be directed downward towards the bottom of the basket to identify when items are placed in the bottom of the basket or taken from the bottom of the basket. For example, some of the carts described herein may include an over-the-basket structural element that couples to a left side and a right side of frame, with a middle portion of this structural element including a camera having an FOV directed substantially downwards into the basket. In addition, this over-the-basket element further include one or more light sources (e.g., LEDs) directed downwards and, in some instances, one or more lighting elements that a user or associate of the facility may selectively turn on to indicate different states of the cart, such as a state in which a user is requesting assistance, a state in which an age of the user is to be verified prior to sale of an item placed into the cart, and/or the like.

In some examples the optical axes of the basket-facing cameras may be directed upward relative to the top of the basket of the cart. For example, the top of the basket of the cart may be disposed in a substantially horizontal plane. The optical axes of the cameras may be directed along the horizontal plane, or upward relative to the horizontal plane, such that the proximity sensors detect the items, and the cameras generate image data representing the items, while the items are at or above the top of the basket (and prior to being placed in a bag or other item carrier). Accordingly, the optical axis of the four example cameras may be directed towards an interior of the perimeter of the top of the basket (e.g., towards a middle or centroid of the perimeter of the basket), and upward relative to a horizontal plane in which the top of the basket is disposed. In this way, the FOVs for each of the cameras may at least partially overlap at a location above, and potentially central to, the perimeter of the top of the cart to define a "sweet spot", "target zone", or "region of interest" where items are detected and/or captures by all four of the cameras. The handle-facing cameras, meanwhile, may generally be oriented toward a handle of the cart and downwards such that the FOVs of these cameras results in the these cameras generating image data of a user operating the cart and placing or removing items into or from a storage location underneath the handle.

To utilize a smart cart as described above, a user may have registered for a user account with an operator of the facility to utilize various automated management services provided by an operator of the facility. For instance, the user may have registered for a user account to automate payments made for items taken by the user and included a payment means (e.g., credit card, bank account number, etc.), and may have also provided an identification means such that the facility, or carts, can recognize the user. For instance, the user may have registered to identify themselves to the cart using any identification technique, such as presenting an identification means to the first camera/scanner positioned on the frame of the cart (e.g., presenting a driver's license, presenting a facility-issued card, presenting a user identifier via a mobile phone, etc.), speaking a predefined utterance (e.g., a name of the user, a predefined keyword, etc.), and/or looking into the first camera for facial recognition. Once a user has identified themselves to a smart cart, the user may begin a shopping session where the smart cart identifies and track items retrieved by the user and placed in the smart cart.

In some instances, the cart may be configured to determine when a user is not proximate the cart (e.g., not within a predefined threshold distance of the cart) and, in response, may turn off or otherwise lessen the amount of power consumed by the one or more components of the cart. For instance, the cart may power off or down image-processing components configured to analyze image data and identify items and actions represented therein, and/or any other hardware, software, and/or firmware components of the cart.

In examples where the smart cart includes proximity sensors, the smart cart may continuously operate the proximity sensors to detect movement of items above the top of the cart. The proximity sensors may generate sensor data that indicates whether an item or object is with a threshold range of distances from the top of the cart (e.g., within 6 inches, within 1 foot, within 2 feet, etc.). The sensor data may be analyzed to detect an item above the perimeter of the top of the cart and trigger the light sources to begin illuminating light and the cameras to begin generating image data. The image data generated by the second camera(s) may be analyzed by the software components to determine whether or not an item is being placed in the cart or removed from the cart. For instance, the image data may represent, over time, movement of the item into the cart, or out of the cart. Additionally, the image data may be analyzed using various techniques to determine an item identifier. Various techniques may be utilized to process image data for identifying the item identifier of the item, such as text recognition, object recognition, and/or other techniques. Upon determining the item identifier, such as determining that the item corresponds to "Strawberry Yogurt," the software components on the cart may store an indication that the item identifier was added to the cart, or removed from the cart, and update a virtual shopping cart accordingly.

After the user has moved throughout the materials handling facility and selected the items they desire to purchase or otherwise take from the facility, the user may end the shopping session in various ways. For instance, the user may return the cart to a cart corral, provide input to the cart indicating an end of the shopping session (e.g., utterance, utilize a user interface element on a touch display, etc.), or simply remove their bags or other item carriers from the cart and leave the facility. After the user has ended their shopping session, the list of item identifiers in the virtual shopping cart may be uploaded to one or more remote servers that manage user accounts for users of the facility. The servers may charge the appropriate user account for the listing of the items in the virtual shopping cart that the user took from the facility.

As introduced above, the smart carts described herein may include one or more cameras for identifying items placed into, or removed from, the respective cart for updating a virtual cart of items associated with a user operating the cart. For instance, an example smart cart may include one or more first cameras directed towards a handle of the cart for identifying items placed into, or removed from, a storage location underneath the handle and at least partly underneath the basket, as well as one or more second cameras directed towards the basket for identifying items placed into, or removed from, the basket. In each instance, the cameras generate image data that may be analyzed by an activity-detection component executing on the smart cart or another device for determining whether the image data represents a predefined activity, such as a user interacting in a region of interest, which may comprise a certain three-dimensional (3D) space adjacent the basket and/or the storage location beneath the handle. If the activity-detection component detects a threshold amount of activity, then an item-identification component executing on the smart cart or another computing device may begin analyzing subsequent image data to attempt to identify items placed into or removed from the cart, or may increase a frame rate at which the item-identification component performs this analysis.

For instance, the activity-detection component may receive an individual frame of data, may generate feature data associated with the frame, and may input this feature data into a trained machine-learning model configured to output an indication of whether the frame represents the predefined activity or not. To make this determination, the model may have been trained using training data that has been labeled to indicate whether each respective frame of the training data represents the predefined activity or does not represent the predefined activity. After training, the model may determine a likelihood that each input frame of image data represents the predefined activity, may compare this likelihood to a threshold, and may output an indication that the frame represents the activity if the likelihood is greater than the threshold or otherwise satisfies one or more criteria. If the likelihood is not greater than the threshold or does not satisfy the one or more criteria, then the model may output an indication that the frame does not represent the predefined activity.

The activity-detection component may store, for each frame, an indication of whether the respective frame was determined to represent the predefined activity. The activity-detection component may then determine, based on these stored indications, whether the predefined activity is occurring at the cart or not. For instance, in a beginning phase, the activity-detection component may store an indication that the cart is currently not experiencing the predefined activity, but may begin analyzing the individual frames to determine whether each frame represents activity. The activity-detection component may then identify that the predefined activity is occurring if, for instance, a threshold number of frames within a sliding window of frames have been determined to represent the predefined activity. For instance, the activity-detection component may analyze the prior ten or other number of frames to determine whether a threshold number (e.g., eight frames) have been determined to represent the predefined activity. If so, then the activity-detection component may store an indication that the cart is currently experiencing the predefined activity, meaning that a user likely reaching into the basket area or other storage location of the cart, potentially to add an item to the cart or remove an item from the cart. Thus, the activity-detection component may store an indication that a transition has occurred from a no-activity time window to a time window associated with the predefined activity.

After identifying the activity time window, the activity-detection component may also send an indication of the detected activity to the item-identification component. In response to receive this indication, the item-identification component may begin analyzing subsequent image data to attempt to identify an item placed into or removed from the cart, or may increase a rate at which this analysis is performed. As will be appreciated, during times of no activity (as determined by the activity-detection component), the item-identification component may be turned off or may operate at a reduced frame rate, thus conserving battery power consumed by the item-identification component. However, upon the activity-detection component identifying activity, the item-identification component may power on or may begin operating at a higher frame in order to increase the likelihood of accurately identifying items placed into or removed from the cart.

In some instances, the item-identification component may analyze each frame of image data using an item- or barcode-localization component, that may identify a region of an individual frame of data that includes an item or a barcode. After such a region has been identified, a reader component of the item-identification component may analyze this region to attempt to identify the item itself, for instance by identifying the barcode of the item, text printed on the item, a shape of the item, or the like.

Meanwhile, during the activity window, the activity-detection component may continue to analyze individual frames of image data to determine whether each respective frame represents the predefined activity. The activity-detection component may continue to store respective indications of whether each individual frame represents the predefined activity. In some instances, the activity-detection component may then determine, based on these stored indications, whether the predefined activity is no longer occurring at the cart. For instance, the activity-detection component may determine whether a threshold number of frames within a sliding window of frames have been determined to not represent the predefined activity. For instance, the activity-detection component may analyze the prior ten or other number of frames to determine whether a threshold number (e.g., seven frames) have been determined to not represent the predefined activity. If so, then the activity-detection component may store an indication that the cart is no longer experiencing the predefined activity, meaning that a user is likely no longer reaching into the basket area or other storage location of the cart, potentially to add an item to the cart or remove an item from the cart. Thus, the activity-detection component may store an indication that a transition has occurred from an activity time window to a no-activity time window associated with the activity.

After identifying the no-activity time window, the activity-detection component may also send an indication of this change to the item-identification component. In response to receiving this indication, the item-identification component may cease analyzing subsequent image data to attempt to identify an item placed into or removed from the cart, or may decrease a rate at which this analysis is performed. By turning off or decreasing the rate at which the item-identification component operates during time windows of no activity, battery power of the cart may be conserved without sacrificing the accuracy of the item-identification component.

As noted above, the activity-detection component identifies activity on a frame-by-frame basis by inputting feature data associated with an individual frame into a model that has been trained using labeled training data. The activity-detection component then identifies time periods of the predefined activity by analyzing a result of these individual frames over a sliding window of time. In some instances, however, the model utilized by the activity-detection component may misidentify one or more individual frames as including activity in instances where they do not, and/or may misidentify one or more individual frames as not including activity in instances where they do. As described below, however, an example smart cart may identify these potential misidentifications, which may be used to re-train the model utilized by the activity-detection component in order to increase the accuracy of this model.

As noted above, the activity-detection component may analyze a sliding window of labels (activity/no activity) applied to prior frames to determine whether the smart cart is currently experiencing an activity window or a no-activity window. Thus, the activity-detection component may identify instances where a frame is identified as representing activity during a time window that is not associated with the activity, and may also identify instances where a frame is identified as not representing activity during a time window that is associated with the activity. The cart may store these frames along with their respective activity/no-activity determinations for potential later user in retraining the activity-detection model. For instance, the cart may send, to a server computing device coupled to the cart: (i) those frames that have been identified as representing activity during a time window that is not associated with the activity, and (ii) those frames that have been identified as not representing activity during a time window that is associated with the activity.

Upon receiving these frames, the server computing device may determine whether the activity-detection component correctly or incorrectly analyzed each of these individual frames. For instance, the server computing device may reanalyze each frame that was determined to represent activity during a time period that is not associated with activity to determine whether that frame in fact represented the predefined activity (e.g., a user placing or removing an item from the cart). In order to make this determination, the server computing device may determine whether the frame represents a body part (e.g., a hand), whether the frame represents a 3D object within the region of interest (e.g., near the basket), whether the frame represents a barcode or item, and/or the like. If the server computing device determines that this frame does in fact represent activity, then the server computing device may take no further action this frame, given that the server has determined that the activity-detection component operating on the cart accurately characterized this frame. If, however, the server computing device determines that the frame does not represent the activity, then the server computing device may re-label the frame as not representing the predefined activity and may store this re-labeled frame as training data for re-training and, thus, updating the model, as discussed above.

In addition, the server computing device may reanalyze each frame that was determined to not represent activity during a time period that is associated with activity to determine whether that frame in fact did not represent the predefined activity (e.g., a user placing or removing an item from the cart). In order to make this determination, the server computing device may determine whether the frame represents a body part (e.g., a hand), whether the frame represents a 3D object within the region of interest (e.g., near the basket), whether the frame represents a barcode or item, and/or the like. If the server computing device determines that this frame does not represent activity, then the server computing device may take no further action this frame, given that the server has determined that the activity-detection component operating on the cart accurately characterized this frame. If, however, the server computing device determines that the frame does represent the activity, then the server computing device may re-label the frame as representing the predefined activity and may store this re-labeled frame as training data for re-training and, thus, updating the model, as discussed above.

After re-labeling and storing the frames that the activity-detection component misidentified (and filtering out the remaining frames that the component accurate identified), the server computing device may then use these re-labeled frames as part of training data for generating an updated activity-detection model. That is, these frames may be added to a set of training data to improve the accuracy of the model. After re-training the model, the server computing device may then test the newly generated (or updated) model on a set of test data having known labels to determine an accuracy (or efficacy rate) of the updated model. If this efficacy rate is greater than the efficacy rate of the current model employed by the smart carts in their respective facilities, the server computing device may send this updated model to the smart carts such that they begin utilizing a more-accurate model, leading to better activity detection and, thus, performance of these smart carts.

While some of the examples below describe an activity-detection component operating as software to identify frames that the model operating on the cart may have misidentified, it is to be appreciated that the activity-detection techniques may additionally or alternatively be performed in hardware in some instances. For instance, a hardware component may be used to identify activity within one or more regions of interest, with the hardware component outputting different voltages to indicate whether activity has been detected. It is to be appreciated that the techniques for improving the accuracy of the model used for performing activity detection may be performed regardless of whether activity detection occurs in hardware, software, or a combination thereof.

It is also to be appreciated that the techniques for correcting the misidentified frames and retraining the model(s) may be performed in real-time, in an offline manner, or in any other manner. For instance, the carts described herein may send the potentially misidentified frames up to the servers for analysis in response to identifying these frames. In other instances, the carts may send these frames up at a later time and the servers may analyze the data in an offline manner. In these instances, the servers may analyze a larger window of frames (e.g., five frames, ten frames, etc.) to identify potentially misidentified frames. That is, the servers may perform the techniques on a frame-by-frame basis or may operate across a larger window of frames. Regardless of the implementation, the techniques may improve the accuracy of the models utilized by the carts as introduced above and described in detail below.

Although some of the techniques described below are performed locally on the cart, in other examples, some or all of the techniques may be performed by one or more backend devices or servers associated with the facility. For instance, the sensor data and/or image data may be collected at the cart and sent over network(s) to backend devices at the facility, or server devices located remote from the facility, to be processed remotely. However, in some instances it may be advantageous for at least some of the processing to be performed on the cart to reduce latency in identifying items placed in the cart. For instance, it may be advantageous to have low latency when requesting that a user provide feedback to help identify an item recently placed in the cart, rather than the user continuing their shopping session and being asked later about an item. Further, although some of the techniques described below are performed on backend devices, in other examples, some or all of the techniques may be performed by locally on the cart. For instance, the techniques described above and below for generating updated models may be performed in whole or in part on the smart cart(s), rather than or in addition to on the server computing devices.

Further, while various techniques described below are with reference to purchasing items in a retail facility, the techniques are generally applicable to any materials handling facility in which a user may place items in a cart. Further, the following description describes use of the techniques within a materials handling facility. The facility described herein may include, but is not limited to, warehouses, distribution centers, cross-docking facilities, order fulfillment facilities, packaging facilities, shipping facilities, rental facilities, libraries, retail stores, wholesale stores, museums, or other facilities or combinations of facilities for performing one or more functions of materials (inventory) handling. In other implementations, the techniques described herein may be implemented in other facilities or situations.

Certain implementations and embodiments of the disclosure will now be described more fully below with reference to the accompanying figures, in which various aspects are shown. However, the various aspects may be implemented in many different forms and should not be construed as limited to the implementations set forth herein. The disclosure encompasses variations of the embodiments, as described herein. Like numbers refer to like elements throughout.

FIG. **1** illustrates an example architecture **100** that includes a user **102** operating a mobile cart **104** within a facility, as well as one or more server computing devices (or "servers") **106** communicatively coupled to the mobile cart **104** or other devices within the facility over one or more networks **108**. As illustrated, the mobile cart **104** may include cameras **110** to generate and store image data **126** and, potentially, one or more additional sensors **112** to generate additional sensor data. As illustrated, the mobile cart **104** may analyze individual frames **114** of the image data **126** using a trained machine-learning model to identify time windows where activity is occurring proximate to the cart **104** and/or to identify time windows where no activity is occurring proximate the cart **104**. For instance, the cart **104** may analyze the frames **114** to determine time windows where predefined activity is occurring near a basket of the cart or other storage location, such as a user reaching into the airspace of the basket or other storage location. Further, while FIG. **1** illustrates the mobile cart using the trained machine-learning model to analyze the frames **114**, in other instances the servers **106** and/or one or more other computing devices may analyze the frames using one or more trained machine-learning models. For instance, the cart **104** may send the image data to the servers **106**, which may analyze the frames **114** to determine predefined activity within individual frames and to determine time windows associated with the predefined activity and time windows that are not associated with the predefined activity. Thus, it is to be appreciated that the techniques described below with reference to both training (and retraining) models and using the models to identify activity may be performed on the carts **104**, at the servers, and/or at one or more other computing devices.

Returning to FIG. **1**, this figure illustrates that the cart **104** has determined a first time window **116(1)** that is not associated with a predefined activity (labeled here as "Activity False"), as well as a time window **116(2)** where the cart **104** has determined that the predefined activity is occurring ("Activity True") and a time window **116(3)** between these two respective time windows ("Activating"). Finally, in this example, the cart has also identified another time window **116(4)** where the predefined activity has ceased (again labeled as "Activity False"). As introduced above and discussed in further detail below, upon the cart **104** identifying the activity window **116(2)**, the cart may begin analyzing the image data **126** to attempt to identify an item placed into or removed from the basket or other storage location of the cart **104**, or may increase a frame rate associate with this analysis.

In some instances, however, the cart **104** may identify discrepancies between the determination made for an individual and the determination made for a window within which the frame occurs. For instance, FIG. **1** illustrates that the cart **104** has identified, as discrepancies, a frame **114(1)** as representing activity (labeled "True") during the window **116(1)** not associated with activity and frames **114(2)** and **114(3)** as not representing activity (labeled "False") during the time window **116(2)** associated with activity. That is, while the cart **104** has determined that the time window **116(1)** as a whole did not represent the predefined activity, the cart has determined that the frame **114(1)** did represent activity. Conversely, while the cart **104** has determined that the time window **116(2)** as a whole did represent the predefined activity, the cart has determined that the frames **114(2)** and **114(3)** did not represent activity. Thus, the cart **104** may store these discrepancies for later, more detailed analysis to determine whether these frames were accurately or inaccurately labeled by the trained model. If it is later determined that one or more of these frames were inaccurately determined by the model, then the labels associated with these frames may be changed to match the new determination and these newly labeled frames may be stored as training data for re-training the model in hopes of increasing the accuracy of the model.

In order to perform these techniques, FIG. **1** illustrates that the mobile cart **104** may include an activity-detection component **118** storing at least one trained machine-learning model **120** for analyzing frames of image data **126** generated by the cameras **110**. For instance, the activity-detection component **118** may generate feature data for individual frames of the image data **126** may input this feature data into the model **120**, which may be trained to output respective labels **128** indicating whether each individual frame represents the predefined activity. For instance, the model **120** may have been trained using frames of image data **126** each labeled to indicate whether the frame represents the predefined activity ("true" or "false").

In addition, the mobile cart may include an activity-smoothing component **122** that receives, as input, an indication of the determination of activity or no-activity on a frame-by-frame basis from the activity-detection component **118** and, in response, determines when to declare an activity window and when to declare a no-activity window (collectively stored as "windows **116**"). For instance, the activity-smoothing component **122** may determine and declare an activity window, such as the activity window **116(2)**, upon determining that a threshold amount of frames within a window of frames of a predetermined size have been associated, by the activity-detection component **118**, with a label **128** indicating that the frame represents activity. For instance, the activity-smoothing component **122** may analyze a sliding window of the ten most recent frames (or any other number of frames) and may determine an activity window upon a threshold number (e.g., eight) frames of the sliding window of ten frames have been determined by the activity-detection component **118** to represent activity.

Further, after determining and declaring an activity window, the activity-smoothing component **122** may determine when to declare a no-activity window, such as the window **116(4)**. Again, the activity-smoothing component **122** may determine and declare a no-activity window upon determining that a threshold amount of frames within a window of frames of a predetermined size have been associated, by the activity-detection component **118**, with a label **128** indicating that the frame does not represent activity. For instance, the activity-smoothing component **122** may analyze a sliding window of the ten most recent frames (or any other number of frames) and may determine a no-activity window upon a threshold number (e.g., eight) frames of the sliding window of ten frames have been determined by the activity-detection component **118** to not represent activity. In some instances, the size of the sliding window and associated threshold may be the same between determining activity and no-activity windows, while in other instances they may differ.

FIG. **1** further illustrates that the mobile cart may include a discrepancy-determination component **124**, which may function to identify discrepancies between the labels applied to individual frames and the windows in which these frames occur. For instance, the discrepancy-determination component **124** may identify those frames that have been determined by the activity-detection component **118** to represent activity in windows that have not been determined to represent activity. In some instances, the discrepancy-determination component **124** may store these discrepancies as "hard negatives **130**". The discrepancy-determination component **124** may also identify those frames that have been determined to not represent activity in windows that have been determined to represent activity. In some instances, the discrepancy-determination component **124** may store these discrepancies as "hard positives **132**". In some instances, the mobile cart **104**, the servers **106**, and/or one or more other computing devices may re-analyze these hard negatives **130** and hard positives **132** to determine whether the activity-detection component **118** accurately determined the respective label of each of these frames. If not, these frames may be re-labeled and then used as training data to update the model **120** or another model used by the activity-detection component **118**.

In this example of FIG. **1**, for instance, the mobile cart **104** may send the hard negatives **130** and hard positives **132** to the servers **106** for re-analysis and, potentially, for using as training data. As illustrated, the servers **106** may include a verification component **134**, a re-training component **136**, and a model-testing component **138**. The servers **106** may further store one or more models **140** for use by the cart **104** and other carts, image data **142** received from the cart **104** and other carts, rule data **144** for determining whether to re-label a hard negative or positive, training data **146** for training the models **140**, and test data for testing the accuracy (or efficacy) of the models **140**.

The verification component **134** may function to re-analyze each received hard negative **130** and hard positive **132** to determine whether the activity-detection component **118** correctly labeled each of these frames. For instance, the verification component **134** may re-analyze the image data **142** associated with each of these frames to determine whether they include activity or not. In some instances, the verification component may analyze the respective image data to determine when a particular 3D volume in the image frame corresponding to a region of interest (e.g., above or in a basket or other storage location of the cart **104**) includes an object, whether the image data represents a body part, whether the image data represents a barcode or item, or the like. As will be appreciated, the verification component **134** may use one or more trained machine-learning models to make this determination. Further, the verification component **134** may analyze the rules data **144** to determine whether or not to label a particular image frame as including activity. The rules data **144** may store any number of rules regarding whether a frame is to be labeled as including activity based on the resulting analysis of the image frame. For instance, the rules data **144** may include a rule indicating that a frame that includes an object in the region of interest is to be labeled as representing activity, that an image frame that includes a body part is to be labeled as representing activity, that an image frame that includes a barcode or item is to be labeled as representing activity, and/or so forth.

Upon the verification component **134** determining that the activity-detection component **118** of the mobile cart has correctly labeled a particular hard positive or hard negative, the verification component **134** may discard or filter out this image frame. That is, the servers **106** may determine that the cart **104** accurately identified what was presumed as a discrepancy and, thus, that data point might not be used to re-train the model in some instances. In instances where the verification component **134** determines that the activity-detection component **118** of the mobile cart has incorrectly labeled a particular hard positive or hard negative, the verification component **134** may re-label this frame and store this re-labeled frame as training data **146** for use in re-training the model(s) **140**. The re-training component **136** may then use the training data **146** to re-train the model(s) **140**, which now include the correctly labeled hard negatives **130** and hard positives **132**. The re-training component **136** may generate a new model based on the re-training of an existing model using the now-supplemented training data **146**.

After a new model **140** has been generated, the model-testing component **138** may determine whether the new model is more accurate than the model(s) currently being used by the cart **104** and/or other carts. To do so, the model-testing component **138** may apply the newly generated model **140** to test data **148** that is associated with known and accurate labels to determine an accuracy or efficacy of the model. Upon determining this accuracy or efficacy, the model-testing component **138** may determine whether this accuracy or efficacy is greater than an accuracy or efficacy of the model **120** currently being used by the cart **104** and/or other mobile carts. If so, then the servers **106** may, upon some trigger event, send the newly generated model to the cart **104** and/or other carts for use by the activity-detection component **118**. The activity-detection component **118** may thus be more accurate in labeling frames as including activity or not and, thus, the activity-smoothing component **122** may be more accurate in identifying activity windows and no-activity windows.

FIG. **2**A illustrates an example schematic diagram of the mobile cart **104** analyzing frames of image of data to detect activity and, upon identifying a threshold amount of frames that represent activity, determine an activity window. In addition, this diagram illustrates the mobile cart **104** identifying frames where a model utilized by the mobile cart **104** may have misidentified a frame that includes activity as not representing activity. The mobile cart **104** may store this frame and associated information for later use in re-training the model to improve the accuracy of the model.

As illustrated, the mobile cart **104** may be associated with one or more regions of interest, such as a region of interest **202**(**1**) and a region of interest **202**(**2**), that the cart **104** may monitor for determining activity therein for the purpose of powering on or up an item-identification component for identifying items placed into or removed from the cart. As illustrated, the region of interest **202**(**1**) may be adjacent to and/or include a storage location of the cart under the handle of the cart and generally adjacent and underneath the basket, while the region of interest **202**(**2**) may be adjacent to and/or include the basket of the cart **104**.

As described above, the cart **104** may include cameras that generate image data, and the activity-detection component **118** may utilize a model **120** to determine, for individual frames of the image data, whether the respective frame represents activity. In this regard, the activity-detection component **118** may store an indication of a label associated with the frame indicating with the frame represents activity. For instance, the activity-detection component **118** may store, in association with each individual frame, a label of "true" (indicating that the frame represents the activity on which the model **120** has been trained) or "false" (indicating that the frame does not represent the activity). In addition, the activity-smoothing component **122** may analyze a sliding window of the most recent image frames and, based on their labels determine whether to declare an activity window or a no-activity window.

FIG. **2**A, for instance, illustrates an example timeline **204** during which the activity-detection component **118** and the activity-smoothing component **122** may analyze frames of image data to determine activity and no-activity windows. For example, FIG. **2**A illustrates that at a time T_1 the activity-detection component has determined a label for each image frame of an example set **206** of twelve image frames, each of which the activity-detection component **118** has labeled as "false" indicating that the respective frame does not include the predefined activity, as determined by the trained model **120**, including a most-recently generated and analyzed frame **208**. In addition, FIG. **2**A illustrates that the activity-smoothing component may analyze a sliding window **210** of the most-recently generated and analyzed image frames for determining whether to declare an activity window. In this example, the sliding window **210** may comprise a most-recent eight frames, although any other number may be used. Further, the threshold number of frames for declaring the beginning of an activity may comprise any number, such as four, six, or the like. In this example, the activity-smoothing component **122** is configured to declare an activity window upon identifying six "true" labels from a previous eight image-frame labels.

At the time T_1, all eight of the eight frames of the sliding window **210** have been determined to not represent activity (as each frame is labeled "F" for false) and, thus, the activity-smoothing component stores an indication the window continues to be one of no activity. Next, FIG. **2**A illustrates that at a time T_2 the next image frame has been determined by the activity-detection component **118** to represent activity. However, the sliding window still only includes one frame labeled as representing the activity of the eight values in the sliding window **210**.

Next, at a time T_2 the next image frame has been determined by the activity-detection component **118** to represent activity. However, the sliding window still only includes two frames labeled as representing the activity of the eight values in the sliding window **210**. Next, at each of times T_4-T_7 the subsequent image frame has been determined by the activity-detection component **118** to represent activity. At this point, six of the eight frames in the sliding window **210** are labeled as representing the activity of the eight values in the sliding window **210**. Thus, the threshold amount of frames representing activity is greater than the threshold and the activity-smoothing component **122** may store an indication of an activity window **214**, which may be configured to begin at an activity-window edge **212**. After determining the activity window **214**, the activity-smoothing component **122** may also send an indication of a the activity window **214** (e.g., a time at which the activity window **214** begins) to an item-identification component configured to begin analyzing the image data for an item represented therein or increase a frame rate of this analysis.

At a time T_{19}, meanwhile, FIG. **2**A illustrates that while the sliding window **210** still indicates that an activity window **214** exists (e.g., because seven of the eight frames are associated with a label of "true"), the discrepancy-detection component **124** has identified a discrepancy **216** in the form of a "hard positive"—that is, an image frame that has been detected as not representing activity within an activity time window **214**. Thus, the discrepancy-detection component **124** may store the discrepancy **216** for later analysis by the cart **104** or the servers **106**. In some instances, the discrepancy-detection component **124** or another component of the cart may send each discrepancy to the servers **106** upon detecting a respective discrepancy, while in other instances this component may send the discrepancies as a batch in response to a trigger event (e.g., a time of day, a request from an operator, etc.).

FIG. **2**B continues the example analysis. At each of subsequent times $T_{20\text{-}25}$ the activity-detection component **118** has determined, by applying feature data of each respective image frame to the trained model **120**, that each respective image frame does not represent activity. Thus, at T_{25} the activity-smoothing component **122** determines that a threshold number of frames within the sliding window **210** are labeled as not representing activity and, thus, the component **122** may store an indication of a no-activity window **220** beginning at a no-activity-window edge **218**. In addition, the activity-smoothing component **122** may send an indication of the beginning of the no-activity window **220** to the item-identification component, which may cease or otherwise slow a rate at which this component attempts to identify items or barcodes within the subsequent image frames.

At a time T_{38}, however, FIG. **2**B illustrates that one of the image frames within the no-activity window **220** has been labeled as including activity. That is, the frame associated with the time T_{34} was determined by the activity-detection component **118** to include activity. Thus, the discrepancy-detection component **124** identifies this image frame as another discrepancy **222** in the form of a "hard negative"—that is, an image frame that has been detected as representing activity within a no-activity time window **220**. Thus, the discrepancy-detection component **124** may store the discrepancy **222** for later analysis by the cart **104** or the servers **106**.

FIGS. **3**A-B collectively illustrate a flow diagram of an example process **300** for analyzing frames of data to detect activity, as well as identify discrepancies where a trained model utilized to analyze the image data may have incorrectly identified a frame as representing activity or not representing activity. The process **300**, as well as each process discussed herein, may be implemented in hardware, software, or a combination thereof. In the context of software, the described operations represent computer-executable instructions stored on one or more computer-readable storage media that, when executed by one or more hardware processors, perform the recited operations. Generally, computer-executable instructions include routines, programs, objects, components, data structures, and the like that perform particular functions or implement particular abstract data types. Those having ordinary skill in the art will readily recognize that certain steps or operations illustrated in the figures above may be eliminated, combined, or performed in an alternate order. Any steps or operations may be performed serially or in parallel. Furthermore, the order in which the operations are described is not intended to be construed as a limitation. In addition, these processes may be performed by the mobile cart **104**, the servers **106**, other computing devices, or a combination thereof. It is also to be appreciated that this process **300**, as well as the other processes and techniques described throughout this disclosure, may be performed in real-time, near-real-time, offline, and/or in any other manner.

An operation **302** represents one or more cameras of a mobile cart **104** generating a frame of image data. As described above, these camera(s) may be oriented towards a basket or other storage location of the cart **104**. An operation **304** represents analyzing the image frame for activity. This operation may comprise the activity-detection component **118** generating feature data and inputting the feature data into a trained model **120** configured to output an indication of whether the frame represents predefined activity for which the model **120** has been trained to identify. An operation **306** represents determining whether the frame is determined to represent activity. If not, an operation **308** represents storing an indication of no activity (e.g., applying a label of "false" to the frame) and the process **300** returns to the operation **302**. If, however, activity is detected in the frame, then the process **300** proceeds to an operation **310**, which represents storing an indication of activity in the frame (e.g. applying a label of "true" to the frame). In addition, given that the cart **104** is in a no-activity state, which is the state a cart may be associated with until the activity-smoothing component **122** identifies an activity window, an operation **312** represents storing an indication of a discrepancy. While not specifically mentioned as part of this process, it is to be appreciated that certain frames within a threshold distance of a transition between window states (e.g., activity to no-activity or vice versa) might not be stored as discrepancies and later analyzed for updating a model.

Next, an operation **314** represents determining whether an activity threshold has been met or whether criteria associated with declaring an activity window has otherwise been met. For instance, this operation may comprise determining whether a threshold amount of image frames within a most recent amount of image frames have bene labeled as representing activity. If not, then the process **300** returns to the operation **302**. If so, however, then the process **300** proceeds to an operation **316**, which represents storing an indication of an activity window. This may also include sending an indication of the activity window to one or more additional components, such as an item-identification component. Next, an operation **318** represents generating another frame of image and an operation **320** represents analyzing the frame for activity. Again, this latter operation may comprise the activity-detection component **118** inputting feature data associated with this image frame into the trained model **120** for receiving, as output of the model **120**, an indication of whether the image frame represents the predefined activity. An operation **322** represents determining whether the frame has been determined to represent activity. If so, then an operation **324** represents storing an indication of activity in the frame, such as storing a "true" label in association with the image frame, and returning to the operation **318**. If activity is not determined in the frame, meanwhile, then the process **300** proceeds to FIG. **3**B.

FIG. **3**B continues the illustration of the process **300** and includes, at an operation **326**, storing an indication that the frame does not include activity. For instance, this operation may comprise storing a "false" label in association with the image frame. Next, an operation **328** represents storing an indication of a discrepancy, given that the frame was determined not to include activity but is associated with an activity window. An operation **330** represents determining whether a no-activity threshold has been met, such as based on the activity-smoothing component **122** determining that a threshold number of frames of a most recent number of frames have been determined to not represent activity. If not, then an operation **332** represents that the process returns to the operation **318**. If so, however, then an operation **334** represents storing an indication of a no-activity window, which may include sending an indication of the no-activity window to the item-identification component or another component. Next, an operation **336** represents determining whether to send the stored discrepancies to a system (e.g., one or more computing devices, such as the servers **106**). If so, then an operation **338** represents sending the discrepancies to the system and, at an operation **340**, returning to the operation **302**. If it is determined not to send the discrepancies, then the process **300** proceeds to return to the operation **302** per the operation **340**. Of course, while this process **300** describes sending the discrepancies to a system for analyzing and, potentially, using these discrepancies to update a trained model, in some instances the cart **104** may perform this analysis and model-update operation.

FIGS. **4**A-B collectively illustrate a flow diagram of another example process **400** for analyzing frames of data to detect activity, as well as identify discrepancies where a trained model utilized to analyze the image data may have incorrectly identified a frame as not representing activity. In some instances, the process **400** may be performed by the mobile cart **104** and/or the servers **106**.

An operation **402** represents causing one or more cameras of a mobile cart to generate a first frame of image data, while an operation **404** represents analyzing the first frame to determine that the first frame represents a predefined activity. For instance, this operation may comprise the activity-detection component **118** inputting feature data associated with the first frame into a trained model **120** to determine whether the frame represents the activity for which the model **120** has been trained to identify. Next, an operation **406** represents determining, after analyzing the first frame to determine that the first frame represents the predefined activity, that a number of frames determined to represent the predefined activity is greater than a first threshold number of frames. For instance, the activity-smoothing component **122** may determine that a threshold number of frames within a number of most-recently generated frames represent the predefined activity. An operation **408** then represents storing an indication that a time window is associated with the predefined activity.

An operation **410** represents causing the one or more cameras to generate a second frame of image data during the time window that is associated with the predefined activity. An operation **412** then represents analyzing the second frame to determine that the second frame does not represent the predefined activity. For instance, this operation may comprise the activity-detection component **118** inputting feature data associated with the second frame into the trained model **120** to determine whether the frame represents the activity for which the model **120** has been trained to identify. An operation **414** represents sending the second frame to a computing device, such as the server(s) **106**, while an operation **416** represents sending, to the computing device, first data indicating that the second frame has been determined to not represent the predefined activity and that the second frame is associated with the time window that is associated with the predefined activity. For instance, this operation may comprise sending the frame to the computing device along with an indication that this frame represents a discrepancy, such as a hard positive.

An operation **418** represents receiving, from the computing device, a machine-learning model that has been trained based at least in part on the second frame and a label indicating that the second frame represents the predefined activity. For instance, this model may comprise an update model relative to the model previously used during the process **400**. An operation **420** represents causing the one or more cameras to generate a third frame of image data.

FIG. **4**B continues the illustration of the process **400** and includes, at an operation **422** analyzing the third frame using the received machine-learning model to determine that the third frame represents the predefined activity. An operation **424** represents determining that a second number of frames determined to not represent the predefined activity is greater than a second threshold number of frames. For instance, the activity-smoothing component **122** may determine that a threshold number of frames within a number of most-recently generated frames do not represent the predefined activity. An operation **426** represents storing an indication that a second time window is not associated with the predefined activity.

An operation **428** represents causing the one or more cameras to generate a fourth frame of image data, while an operation **430** represents analyzing the fourth frame to determine that the fourth frame represents the predefined activity. An operation **432** represents sending the fourth frame to the computing device, while an operation **434** represents sending, to the computing device, second data indicating that the fourth frame has been determined to represent the predefined activity and is associated with a second time window that is not associated with the predefined activity. For instance, this operation may comprise sending the frame to the computing device along with an indication that this frame represents a discrepancy, such as a hard negative.

An operation **436** represents receiving, from the computing device, an updated machine-learning model that has been trained based at least in part on the fourth frame and a label indicating that the fourth frame does not represent the predefined activity. An operation **438** represents causing the one or more cameras to generate a fifth frame of image data, while an operation **440** represents analyzing the fifth frame, using the machine-learning model received at the operation **436**, to determine that the fifth frame represents the predefined activity.

FIG. **5** illustrates a flow diagram of another example process **500** for analyzing frames of data to detect activity, as well as identify discrepancies where a trained model utilized to analyze the image data may have incorrectly identified a frame as representing activity. In some instances, the process **400** may be performed by the mobile cart **104** and/or the servers **106**.

An operation **502** represents analyzing, at a first rate during a first time period, frames of image data generated by the one or more cameras to identify at least one of an item or a barcode. For instance, an item-identification component executing on the mobile cart **104** may analyze the image data to at this first rate. An operation **504** represents causing one or more cameras of the mobile cart to generate a first frame of image data, while an operation **506** represents analyzing the first frame to determine that the first frame represents a predefined activity. For instance, the activity-detection component **118** may use a model stored on the mobile cart to perform this analysis.

An operation **508** represents sending the first frame to a computing device, such as the server(s) **106**, while an operation **510** represents sending, to the computing device, first data indicating that the first frame has been determined to represent the predefined activity and that the first frame is associated with a time window that is not associated with the predefined activity. For instance, this operation may comprise sending the frame to the computing device along with an indication that this frame represents a discrepancy, such as a hard negative.

An operation **512** represents receiving, from the computing device, an updated machine-learning model that has been trained based at least in part on the first frame and a label indicating that the first frame does not represent the predefined activity. An operation **514** represents causing the one or more cameras to generate a second frame of image data, while an operation **516** represents analyzing the second frame using the newly received machine-learning model to determine whether the second frame represents the predefined activity.

An operation **518** determining that a second time period subsequent to the first time period is associated with the predefined activity. For instance, this operation may comprise the activity-smoothing component **122** determining that a threshold number of frames within a most recent number of analyzed frames have been labeled as representing the activity. Next, and potentially in response, an operation **520** represents analyzing frames of image data generated by the one or more cameras during the second time period to identify at least one of an item or a barcode at a second rate that is greater than the first rate. For instance, the item-identification component may increase a rate at which it analyzes the image data to identify an item or barcode based on receiving the indication that an activity window has been detected by the activity-smoothing component **122**.

FIG. **6** illustrates a flow diagram of an example process **600** for using new training data generated from misidentified frames to generate an update model to more accurately identify activity within a mobile cart or otherwise. In some instances, the process **400** may be performed by the mobile cart **104** and/or the servers **106**.

An operation **602** represents receiving, at a computing device (e.g., the server(s) **106**), a first frame of image data generated by one or more cameras of a mobile cart, while an operation **604** represents receiving, at the computing device, first data indicating that the first frame was determined, by a first machine-learning model operating on the mobile cart, to not represent a predefined activity. Next, an operation **606** represents receiving, at the computing device, second data indicating that the first frame is associated with a time window that was determined to represent the predefined activity, the time window associated with at least a second frame of image data that was determined by the first machine-learning model to represent the predefined activity. An operation **608** represents analyzing the first frame.

An operation **610** represents determining, based at least in part on the analyzing, that the first frame represents the predefined activity. For instance, the verification component **134** of the server(s) **106** may analyze the first frame to detect a body part, an object with a predefined 3D volume, an item or barcode, or the like, such that the server(s) determine that the first frame represents the predefined activity. An operation **612** represents generating a second machine-learning model based at least in part on the first frame and a label indicating that the first frame represents the predefined activity. For instance, the re-training component **136** of the server(s) **106** may generate a new model by using the re-labeled first frame as training data.

An operation **614** represents determining a first efficacy rate of the first machine-learning model, the first efficacy rate based at least in part on applying the first machine-learning model to labeled test data. For instance, the model-testing component **138** of the server(s) **106** may determine an accuracy of the first model by applying the first model to the test data having labels that are known to be correct. An operation **616** represents applying the second-machine-learning model to the labeled test data to determine a second efficacy rate associated with the second machine-learning model. For instance, the model-testing component **138** of the server(s) **106** may determine an accuracy of the second model by applying the second model to the test data having labels that are known to be correct. An operation **618** represents determining that the second efficacy rate is greater than the first efficacy rate and, in response, an operation **620** represents sending the second model to the mobile cart **104** and/or one or more other mobile carts. In some instances, the server(s) **106** may send the updated model to the cart **104** and/or other carts in response to determining a triggering event, such as a time of day, day of the month, percentage increase in accuracy between an existing model and a new model, and/or the like.

FIG. **7**A illustrates additional details of an example mobile cart **104**. As illustrated, the example mobile cart **104** includes cameras **702**(**1**) and **702**(**2**) pointed toward a basket of the cart for generating image data that may be used to determine when a user is placing an item into or removing an item from the basket, as well as to identify the item and a quantity of the item. As illustrated, the cart **104** may also include one or more light sources **704** between the cameras **702**(**1**) and **702**(**2**), to the left of these cameras, and/or to the right of these cameras.

FIG. **7**B, meanwhile, illustrates that the example mobile cart **104** may additionally or alternatively include cameras **702**(**3**) and **702**(**4**) also having field-of-views (FOVs) directed towards the basket of the cart. Collectively, the cameras **702**(**1**)-(**4**) may generate image data that may be analyzed by components of the cart (or servers **106**) to identify activity within the region of interest **202**(**2**). In addition, the cart **104** may include camera **702**(**5**) and **702**(**6**) directed towards and in some instances downwards from a handle **706** of the cart **104**. Collectively, the cameras **702** (**5**)-(**6**) may generate image data that may be analyzed by components of the cart (or servers **106**) to identify activity within the region of interest **202**(**1**).

FIG. **8** illustrates an example environment **800** of a materials handling facility **802** that includes an item-identifying cart **804** to identify items **806** placed in, and removed from, a basket of the cart **804** by an example user **808**. In some instances, the cart **804** corresponds to the cart **804** described above, or otherwise includes functionality for determining when a user is not proximate the cart (e.g., not within a threshold distance of the cart) and, in response, powers off or down one or more components of the cart. The cart may generate first image data for identifying a user and generate second image data depicting the item **806**. In addition, the cart may analyze the second image data to identify an item identifier for the item **806**, determine the event **810** involving the item (e.g., add to cart, remove from cart, multiple items, quantity of items, etc.) and update a virtual shopping cart associated with the identified user **808** using the item identifier.

As FIG. **1** depicts, the user **808** may have engaged in a shopping session in the materials handling facility **802**. For instance, the user **808** may have selected an item **806** from an inventory location **812** (e.g., shelf, aisle, etc.) and placed the item **806** in the cart **804** (e.g., shopping cart). The inventory location **812** may house one or more different types of items **806** and the user **808** may pick (i.e., take, retrieve, etc.) one of these items **806**.

As illustrated, the materials handling facility **802** (or "facility") may have one or more entry locations **814**, such as lanes. The entry location **814** may be defined by a gate in some examples and may include a movable barrier to control movement of users **808**. For example, the gate may include computer-controlled panels that may be closed to impede passage of the users **808** or opened to permit passage of the user **808**. Upon entering a facility **802**, a user **808** may desire to utilize a cart **804** for their shopping session to transport items **806** around the facility **802** during their shopping session. In such examples, the user **808** may approach a cart corral **816**, or other locations, at which carts **804** are stored. In some examples, the cart corral **816** may comprise a structure, such as an aisle, for storing nested carts **818**.

Generally, two or more of the carts **804** may be configured to nest or otherwise functionality join with one another, so that the carts **804** may be easily stored in a cart corral **816**, and/or transported in bulk. In some examples, the cart corral **816** may provide additional functionality beyond storage. For instance, the cart corral **816** may facilitate charging of the nested carts **818** that are in the cart corral **816**. For instance, the cart corral **816** may have various electrical contacts extending along the length of a horizontal and/or vertical member of the corral **816** that, when placed in electrical contact with an electrical contact of the nested carts **818**, charge one or more batteries of the nested carts **818**. In other examples, power cords may extend from the cart corral **816** that may be plugged into the nested carts **818** to recharge batteries of the nested carts **818** while not in use.

In some instances, as described above, each of the nested carts **818** may reside in a low-power (e.g., deep-sleep) state when in the cart corral. For instance, the proximity sensors may detect an object (e.g., another cart) very near and, in response, may cause the respective cart to enter the low-power state. In addition, or in the alternative, each cart may include a mechanical switch that may be actuated when placed into the cart corral **816**, resulting in the cart entering the low-power state. In still other instances, when the cart corral **816** includes the electrical contacts to contact with corresponding contacts of the nested carts **818**, each cart may use this signal to cause the cart to enter the low-power state. Of course, while a few examples are provided, the carts may enter the low-power state in any number of ways when nested with other carts in the corral **816**.

To utilize a cart **804**, a user **808** may approach an unused cart that is not currently engaged in a shopping session (e.g., a nested cart **818**), and interact with the unused cart **804** to identify themselves to the cart **804** and begin a shopping session. For instance, the carts **804** may include a first imaging device **834(1)** (e.g., an image sensor such as a camera, photodetector, or other sensing apparatus designed to read a one or two-dimensional barcode) such that when a user **808** presents a user device, or portion thereof, such as the display, to the imaging device **834(1)**, the cart **804** may identify the user and corresponding user account for a shopping session. Other types of interaction may be performed by a user **808** to identify themselves to a cart **804** (e.g., uttering a name or other keyword to identify the user **808**, presenting the user's face for facial recognition, typing in a password or other user information into a display of the cart **804**, and/or any other type of user identification technique).

Further, in some instances the cart **804** may transition from a low-power state to a higher-power state in response to the user approaching the cart **804** and/or removing the cart **804** from the corral **816**. For instance, the imaging devices **834** and/or the proximity sensors may identify the user approaching (e.g., entering within the threshold distance of the cart **804**) and, in response, may cause the cart to enter the higher-power state by, for example, powering on and/or up one or more components that were previously powered off and/or down. In another example, removing the cart **804** from the corral **816** may cause the mechanical switch to trip or may cause the electrical contacts of the corral **816** to become uncoupled from the contacts of the cart **804**, resulting in the cart entering the higher-power state. Again, while a few examples are provided, it is to be appreciated that the cart may transition from a low-power state to a higher-power state in response to being removed from the corral **816** and/or in response to a user approaching the cart **804** in any number of other ways.

Once a user has identified themselves to the cart **804**, the item-identifying functionality of the cart **804** may be activated such that subsequent items **806** placed in the cart **804** will be identified by the cart **804** and added to a virtual shopping cart for the user **808**. As illustrated, a user **808** may move the cart **804** around the facility **802** to one or more inventory locations **812**. The user **808** may retrieve items from the inventory location **812** and place the items **806** in the cart **804**. Additionally, the user may retrieve items **806** from the cart **804** and put the items **806** back in an inventory location **812**, such as when the user **808** changes their mind regarding their desire to purchase or otherwise acquire the item **806**. The cart **804** may include various components for identifying item identifiers corresponding to the items **806** placed in the cart and maintaining a virtual shopping cart for the shopping session of the user **808**.

Once the user **808** has finished their shopping session, the user **808** may end the shopping session in various ways. For instance, the user **808** may return the cart **804** to the cart corral **816**, provide input to the cart **804** indicating an end of the shopping session (e.g., utterance, utilize a user interface element on a touch display, etc.), or simply remove item bags or other item carriers from the cart **804** and leave the facility **802**. After the user **808** has ended their shopping session, the list of item identifiers in the virtual shopping cart may be uploaded to one or more remote servers **820**, over one or more networks **822**, that manage user accounts for users **808** of the facility **802**. The server(s) **820** may charge the appropriate user account for the listing of the items in the virtual shopping cart that the user took from the facility **802**. For instance, the server(s) **820** may be configured to determine or generate information indicative of a cost of the items **806** picked by the user **808**. Additionally, the server(s) **820** may store payment information (e.g., credit card information, bank account information, etc.) for each user account. In this way, when the user **808** finished their shopping session and the cart **804** sends the listing of item identifiers in the virtual shopping cart over the network(s) **822** to the server(s) **820**, the server(s) **820** may be configured to determine a cost or price for all of the listed item identifiers, and charge the user via their payment information for the items **806** selected during their shopping session. In this way, the user **808** need not go through steps of a traditional check-out experience (e.g., waiting in line for a cashier, scanning items with the cashier, paying for items at the cashier, etc.).

The network(s) **822** may include private networks such as an institutional or personal intranet, public networks such as the Internet, or a combination thereof. The network(s) **822** may utilize wired technologies (e.g., wires, fiber optic cable, and so forth), wireless technologies (e.g., radio frequency, infrared, acoustic, optical, and so forth), or other connection technologies. The network(s) **822** is representative of any type of communication network, including one or more of data networks or voice networks. The network(s) **822** may be implemented using wired infrastructure (e.g., copper cable, fiber optic cable, and so forth), a wireless infrastructure (e.g., cellular, microwave, satellite, etc.), or other connection technologies.

The cart **804** may include communication interface(s) such as devices configured to couple to personal area networks (PANs), wired and wireless local area networks (LANs), wired and wireless wide area networks (WANs), and so forth. For example, the communication interfaces may include devices compatible with Ethernet, Wi-Fi™, and so forth. In some examples, the communication interface(s) may encode the data prior to sending over the network(s) **822** according to the type of protocol or standard being used. As noted above, in some examples, the servers **820** may perform some or all of the operations described below as being performed by the cart **804**. While the servers **820** are illustrated as being in a location outside of the facility **802**, in other implementations, at least a portion of the servers **822** may be located at the facility **802**.

As illustrated, the cart **804** may generally include or be formed of a frame **824**, a basket **826**, a first handle **828(1)** for pushing the cart **804**, a second handle **828(2)** for pulling the cart, a wheel frame **830**, and one or more wheel castors **832** to enable movement of the cart **804** on a surface. The frame **824**, the basket **826**, the handles **828**, and the wheel frame **830** may be formed from any suitable materials such as plastics, wood, metals, composites or any other combinations of materials. Moreover, frame **824**, the basket **826**, the handle **828**, and the wheel frame **830** may take any form.

The basket **826** may generally be part of the frame **824** and/or supported by the frame **824** (e.g., be welded, fused, adhered, bolted, screwed, molded, or otherwise joined to the frame **824**). In some examples, the basket **826** may comprise a grid or lattice-like structure (e.g., a honeycombed arrangement or framework) having one or more bars or members that are welded, fused, adhered, bolted, screwed, molded, stitched or otherwise joined in a substantially perpendicular alignment with respect to one another. The basket **826** may generally be any shape that defines an interior cavity, or receptacle, for receiving items **806** that are placed in the cart **804**. The basket **826** may comprise a bottom, multiple sides protruding from the bottom, and a top. As illustrated, the bottom basket **826** may be in the shape of a quadrilateral such that there are four sides protruding from the bottom of the basket **826**. Similarly, the top of the basket **826** may be defined according to the quadrilateral shape and have a perimeter with four corners. The perimeter of the top of the basket **826** may define an opening to the interior cavity (or receptacle) of the basket **826** to receive items placed inside the basket **826**. In various examples, the perimeter of the top of the basket may be disposed in a substantially horizontal plane (e.g., a plane substantially along the x-axis as illustrated), and the frame **824** may include at least one vertical member that extends downward from the basket **826** to the wheel frame **830** along a substantially vertical plane (e.g., a plane substantially along the y-axis as illustrated).

The wheel frame **830** may support one or more wheel castors **832** to enable movement of the cart **804** along a surface. The wheel castors **832** include one or more wheels, axles, forks, joints or other components which enable the cart **804** to travel on various surfaces. For example, in some implementations each of the wheel castors **832** may include a single wheel provided on an axle within a fork, or two or more wheels provided on such an axle. In some other implementations, the wheel castors **832** may include two or more axles. Alternatively, in still other implementations, a single caster may be provided in lieu of the multiple wheel castors **832** shown in FIG. **8**. In accordance with the present disclosure, the wheel castors **832** may operate in any manner, such as being configured to pivot or swivel, and thus automatically adjust or align with a direction of travel. In some examples, the cart **804** may be equipped with other apparatuses for enabling the cart **804** to travel on solid surfaces, including one or more wheeled components other than castors, including but not limited to omnidirectional wheels, spherical wheels or other like apparatuses. Additionally, in some other implementations, the cart **804** may include two or more skis or other runners for traveling on smooth surfaces. In still other implementations, the cart **804** may be levitated, e.g., by magnetic levitation through the use of one or more linear induction motors. Moreover, the cart **804** may be propelled or pushed by humans or autonomous mobile robots or, alternatively, by one or more motors (e.g., electric-powered or gasoline-powered).

As illustrated, the cart **804** may include a first imaging device **834(1)**, for identifying a user operating the cart, as well identifying items placed in a storage location underneath the handle and underneath and adjacent the basket **826**, as described above. In addition, the cart **804** may include second imaging devices **834(2)**, **834(3)**, **834(4)** . . . , **834**(N) that include components for use in identifying items placed in the basket **826** and removed from the basket **826**. The imaging device **834(1)** may, in some instances, be positioned in a manner such that an FOV of the imaging device **834(1)** is away from the basket **826** and substantially towards the first handle **828(1)** where a user may typically operate the cart **804**. The imaging devices **834(2)**-(N) may be positioned at any location on the cart **804** (e.g., in the basket **826**, on the basket **826**, mounted to the frame **824**, mounted to the basket **826**, and/or any other location), oriented to have respective FOVs for identifying events that occur within and proximate to the basket **826**. In some examples, the cart **804** may include at least four of the second imaging devices **834(1)**, **834(2)**, **834(3)**, and **834**(N) that are disposed or coupled proximate to four corners of the top of the basket **826**. In some examples, one or all of the components of the second imaging devices may be disposed internal to the form factor of the basket **826** and/or frame **824**, at least partially internal to the form factor of the basket **826** and/or frame **824**, and/or entirely external to the form factor of the basket **826** and/or frame **824** (e.g., mounted to the cart **804**). However, in the illustrated example, the second imaging devices may be disposed at locations proximate to the four corners of the top or perimeter of the basket **826**/frame **824**. In some instances, the less that the second imaging devices protrude from the form factor of the cart **804**, the more efficiently the carts **804** may be nested with respect to each other.

As described in further detail below with respect to FIG. **9**, the cart **804** may further include one or more one light sources (e.g., LED) for emitting light at or prior to the time of the second imaging devices generating the second image data. The cart **804** may further include, in some instances, one or more proximity sensors (e.g., ToF sensor, PIR sensor, etc.). In some examples the proximity sensors may be activated to detect the proximity of users, objects above the top of the basket **826**, and/or other objects. The proximity sensors may be configured to generate sensor data that indicates distances between objects above the top of the basket **826** of the cart **804** and the second imaging devices. The cart **804** may include components configured to analyze the sensor data and determine that an item **806** is within some threshold distance from the top of the basket **826** and/or within the basket **826**. Upon detecting an object within the threshold proximity of the basket **826** using the proximity sensor, one or more components of the cart **804** may cause the light sources (LEDs) to emit light and the second imaging devices to generate image data. In some examples, the FOVs of the second imaging devices **834(2)**-(N) may each at least partially overlap at a location above the top of the basket **826** corresponding to a centroid of the quadrilateral defining the top of the basket **826**. The light sources may illuminate the basket **826** and/or the area above the top of the basket **826** to illuminate items **806** being placed in the cart **804**, or removed from the cart **804**, to act as a "flash" for the cameras that are generating image data. The second imaging devices may generate image data for a predefined period of time and/or until the proximity sensors (or the image data itself) indicates that there is no longer an object within the threshold distance from the cart **804** or top of the cart **804**.

After generating the image data, one or more components of the cart **804** may process the image data to determine an item identifier for the item(s) **806** represented in the image data, and an event **810** for the image data (e.g., addition of an item **806** to the cart, removal of an item **806** from the cart). As described in more detail below with respect to FIG. **14**, the cart **804** may include component(s) to determine an item **806** identifier for the item **806** (e.g., name of the item **806**, SKU number for the item **806**, etc.), and determine if the item **806** is being taken from the cart **804**, or added to the cart **804**, based on the motion of the item **806** and the result of the movement around the cart **804** once movement is no longer detected and represented by the image data. The components of the cart **804** may then update a virtual shopping cart associated with the cart **804** that indicates a virtual listing of items **806** taken by the user **808** from the facility based on the determined event **810**. In some examples, the image data may be transmitted to the server(s) **820** over the network(s) **822** where the processing may be performed.

In various examples, the cart **804** may include a display **836** to present various information in user interface(s) for the user **808** to consume. In some examples, the display **836** may comprise a touch screen to receive input from the user **808** (e.g., a selection of an item identifier to disambiguate amongst potential item identifiers). In some instances, the display **836** may present customized information to the user **808** upon identifying the user **808**, such as a shopping list of the user or the like.

The cart **804** may further include a battery pack module **838** that houses one or more batteries to power the components of the cart **804**. The battery pack module **838** may include rechargeable batteries. In some examples, the battery pack module **838** may be detachably coupled to the wheel frame **830** and/or the frame **824** of the cart **804** such that the battery pack module **838** may be removed and taken to a charging station. In various examples, the battery pack module **838** may include rechargeable batteries that may be charged when the cart **804** is placed in a cart corral **816** (e.g., through electrical contacts, power cords, etc.). In various examples, the frame **824** and/or basket **826** may have one or more channels (e.g., grooves, holes, paths, tunnels, etc.) through which power cables/cords may pass. In this way, power cables may be run at least partially through the channels in the frame **824** and/or basket **826** inconspicuously to provide power to the various components of the cart **804**.

In some instances, the cart **804** may further include one or more lighting elements **840** disposed on the frame **824** and/or basket **826** of the cart **804**. The user **808** may, in some instances, operate a controller to turn on (and off) the lighting element(s) **840** to cause the lighting element(s) to emit light. Further, in some instances the controller may enable the lighting element(s) **840** to transition between multiple light states, such as different colors, flashing effects, and/or the like. The controller operable by the user **808** may comprise functionality accessible to the user **808** via the display (e.g., one or more soft buttons for turning on and/or off the light), a physical toggle switch on the frame **824** of the cart **804**, and/or the light. Further, the lighting element(s) **840** may be used to signal a predefined state of the cart **804** and/or the user **808**. For example, the user **808** may turn on the lighting element(s) **840** to indicate that he or she requests assistance from an associate of the facility **802**, or for any other reason. In some instances, in response to the user **808** operating a controller to request assistance, the cart **804** may perform one or more actions in addition to turning on the lighting element(s) **840**. For example, the display may present content responding to this request, such as an offer to connect the user **808** with an associate of the store (e.g., in person, via I/O devices of the cart, etc.). For example, in response to requesting assistance, the cart **804** may facilitate an audio-only or an audio/video call between the user **808** and an associate of the facility using one or more I/O devices on the cart, such as the display, one or more speakers, one or more microphones, one or more cameras pointed toward the user **808** and/or the like.

In still other instances, associates of the facility may, remotely or otherwise, operate the lighting element(s) **840** to change states (e.g., turn on or off) and/or the cart **804** may include components to automatically change a state of the lighting element(s) **840**. For example, upon the card identifying that an item of a predefined class of items has entered the basket, the cart **804** may cause the lighting element(s) **840** to change state (e.g., from an off state to an on state) to indicate that an additional checkout workflow may now be required. For example, if the user **808** places an item into the basket **826** that requires the purchasing user to be of a certain age (e.g., alcohol) or to have a certain prescription (e.g., medicine), the cart **804** may illuminate the lighting element (s). In some instances, the cart **804** may include a lighting element on a right side of the frame, a lighting element on a left side of the frame, and/or one or more other lighting elements in other locations on the cart **804**.

FIG. **9** illustrates the cart **804** of FIG. **8** in further detail. As illustrated, the cart may include the first imaging device **834(1)** for identifying a user, the one or more second imaging devices **834(2)**-(N) for identifying items placed into or removed from the basket **826**, the display **836** for presenting information to a user operating the cart **804**, and the one or more lighting elements **840**. In addition, the cart **804** may include one or more light sources **902** that function to emit light prior to and/or while the second imaging sensors **834(2)**-(N) generate the second image data for identifying items placed into and removed from the basket **826**. In some instances, these light sources **902** emit constant light, while in other instances the light sources **802** emit light in a strobing manner. In either of these instances, the light may be visible and/or non-visible light.

In addition, the cart may include one or more caddies, such as a caddy **904**(**1**) and a caddy **904**(**2**), coupled to the left and/or right side of the frame or basket of the cart **804**. For example, the cart **804** may include the first and second caddies **904**(**1**) and **904**(**2**) on the right side of the cart, and two similarly situated caddies on the left side of the cart (not shown). Each caddy may define a receptacle (e.g., having an opening at the top) for housing one or more items therein. In some instances, the caddies may be beyond the FOV of the second imaging devices **834**(**2**)-(N) such that the user is able to place personal items (e.g., keys, wallet, phone, etc.) into the receptacle defined by the respective caddy without the imaging devices **834**(**2**)-(N) generating image data corresponding to this addition. In other instances, the caddies may be within the FOV of one or more of the imaging devices.

In addition, the cart **804** may include one or more respective weight sensors **906** for determining a current weight of the basket **826** and, thus, items in the basket **826**. For example, one or more weight sensors **906** comprising strain gauges or the like may reside underneath the basket **826**. In some instance the bottom platform of the cart may also include one or more weight sensors for determining the weight of items on the bottom platform. Further, in some in some instances each caddy may comprise a respective weight sensor **906** comprising a strain gauge or other sensor that continuously or periodically may be used to determine a weight of the basket and/or whether a change in weight has occurred. For instance, the cart **804** may include two weight sensors **906** on each side of the basket **826**. Each pair of weight sensors **906** may, in some instances, reside along the same vertical axis. That is, a top weight sensor on the right side of the basket **826** may reside above a bottom weight sensor on the right side.

Regardless of the location of the weight sensors **906**, the weight data may be used to identify when items have been placed into or removed from the basket and, in some instances, may be used to identify items placed into or removed from the basket. For example, the weight data may be used to determine the identity of an item placed into or removed from the basket (e.g., to identify that a bottle of ketchup was placed into the basket), identify a number of instances of an item (e.g., a number of bottles of ketchup placed into the basket), to measure an amount of something (e.g. 1 pound of peanuts), and/or the like.

FIG. **9** further illustrates that the cart **804** may include one or more bag clips, such as a bag clip **908**(**1**) on a right side of the basket **826** and a bag clip **908**(**2**) on a left side of the basket **826**. As illustrated, the bag clips **808** may reside on an outside, top portion of the basket such that a user may place a bag into the interior of the basket while securing a first strap of the bag to the first clip **908**(**1**) and a second strap of the bag to the second clip **908**(**2**). Thereafter, the user may place items into and/or remove items from the bag. At the end of the shopping session, the user may remove the bag containing the items from the basket (e.g., by removing the straps from the clips) and exit the facility.

FIG. **9** further illustrates that the cart **804** may include one or more RFID antenna(s) **910**, which may be used for determining a location of the cart **804** within the facility **802**. In some instances, the inventory locations **812** may include respective RFID tags that may be read by the RFID antennas **910** of the cart. In some instances, the cart **804**, or a remote system communicatively coupled to the cart **804**, may store map data that indicates associations between respective location with the facility to respective RFID tags throughout the facility. As illustrated, in some instances the RFID antennas **910** may reside near a bottom portion of the frame of the cart. For instance, the cart **804** may include an RFID antenna near a bottom portion of the right side of the frame and an RFID antenna near a bottom of the left side of the frame. In other instances, however, the RFID antennas **910** may reside at other locations on the cart **804** and/or distributed at multiple locations on the cart **804**.

FIG. **10**A illustrates an example cross-sectional view of an item-identifying cart **1000** that includes imaging device **834** for identifying items **806** placed in the cart **1000**. Again, the cart **1000** may include the proximity sensors and corresponding functionality as described above with reference to the cart **804**. While this cart **1000** may have a different form factors than other carts illustrated and described herein, characteristics of the cart **1000** may be applied to the other cart form factors, and vice versa. As illustrated, the cross-section of the cart **1000** is taken along a plane defined by the x-axis and y-axis along the center of the cart **1000** from the back to the front of the cart **1000**.

In some examples, the imaging device **834**(**2**) is positioned at a first corner of the basket **826** near the back of the cart **1000**. The imaging device **834**(**2**) may have an optical axis **1004** and an FOV **1006** oriented along the x-y plane. The optical axis **1004** of the first capture assembly **834**(**1**) may be directed upward from a substantially horizontal plane **1008** and towards the interior of the perimeter **1010** of the basket **826**. In some examples, the basket **826** may include a bottom of the basket **1012**, ones or more sides of the basket **1014** protruding up from the bottom **1012**, and a top of the basket (perimeter) **1010** that is disposed along the substantially horizontal plane **1008**. In some examples, the FOV **1006** of each of the second imaging devices may have a lower edge that is defined according to the horizontal plane **1008**.

The first imaging device **834**(**2**) may have an optical axis **1004** directed upward from the substantially horizontal plane **1008** and towards the interior of the perimeter **1010** of the basket **826**. In some examples, the FOV ($\theta_{x,y}$) **1006** may be defined according to the optical axis **1004** (e.g., the optical axis **1004** may be approximately the middle of the FOV **1006**). The FOV **1006** may be any FOV for of the second imaging devices (e.g., 80 degrees, 80 degrees, 45 degrees, etc.). Generally, the FOV **1006** may at least partially include an area above the top of the basket **210**. Similarly, another imaging device **834**(**4**) coupled proximate to a corner of the basket **826** on the front of the cart **1000**. The imaging device **834**(**4**) may have an optical axis **1004** directed upward from the substantially horizontal plane **1008** and towards the interior of the perimeter **1010** of the basket **826**. In some examples, the FOVs **1006** may include an area above the top **1010** of the cart **1000**, an area within the basket **826** of the cart, and/or a combination of above and below the top **1010** of the basket **826**.

FIG. **10**B illustrates an example top view of an item-identifying cart **1000** that has imaging devices **834**(**2**)-(N) for identifying items **806** placed in the cart **1000**. As illustrated, the cart **1000** is shown from a top such that the dimensions of the cart **1000** are illustrated along an x-axis and a z-axis (x-z coordinate plane).

In some examples, four imaging devices **834** are positioned at four different corners of the frame **824** and/or basket **826** of the cart **1000**. Each of the four imaging devices **834** may include respective optical axes **1018** directed inward relative to the perimeter **1010** of the basket **826**. Additionally, the four imaging devices **834**(**2**)-(N) may each have FOVs ($\theta_{x,z}$) **1020** that are defined according to the optical axes **1018** (e.g., the optical axes **1018** may be approximately the middle of the FOVs **1020**). The FOVs **1020** may be any FOV for cameras in the imaging devices (e.g., 80 degrees, 80 degrees, 45 degrees, etc.). Generally, the FOVs **1020** for each of imaging devices **834** may overlap at least partially at a centroid **1022** of the frame **824** and/or basket **826** of the cart **1000**. The FOVs **1020** may, in combination, cover all, or most, of the interior of the perimeter **1010** of the basket **826** such that items **806** are detected and identified using at least one of the capture assemblies **834**.

FIG. **10**C illustrates an example perspective view of an item-identifying cart **1000** that has imaging devices **834** for identifying items **806** placed into the cart **1000**. As illustrated, the cart **1000** may include multiple imaging devices that have viewing frustums **1026** that may be oriented in the same direction as the optical axis **1004**. The viewing frustums **1026** may generally be the region of space in the environment of the cart **1000** that is within the field of view of the camera and/or proximity sensor of the imaging devices **834**. The viewing frustums **1026** for each of the imaging devices **834** may be oriented inward to the basket **826** of the cart, and upward relative to the top, or perimeter, of the basket. The proximity sensor, if present, and imaging devices may have the same viewing frustum **1026**, or different viewing frustum's **1026** that at least partially overlap.

FIG. **10**D illustrates another example perspective view of an item-identifying cart **1000** that has imaging devices **834** for identifying items **806** placed into the cart **1000**. As shown in FIG. **6**D, the viewing frustums **1026** and/or FOV's **1006** for each of the imaging devices **834** may generally define the region of interest **202(2)**. The region of interest **202(2)** may comprise a volumetric, three-dimensional (3D) shape in which items **806** are captured in image data of the cameras, and/or detected by proximity sensors. Thus, the region of interest **202(2)** defines a volumetric region in which at least one of the cameras in a capture assembly is able to capture image data representing an item **806**. Generally, the region of interest **202(2)** may encompass substantially all, or a large majority of, the perimeter of the top of the basket. In this way, items **806** placed in the basket **826** will be detected and have image data generated that represents the items **806** as they are being placed in the basket **826**. Although illustrated as including space above the basket **826**, in some examples, the region of interest **202(2)** may additionally, or alternatively, include space inside the basket **826** (e.g., downward facing cameras). In some instances, the region of interest **202(2)** defined by the cameras on the cart **1000** may be the same as the region of interest **202(2)** of the proximity sensors, or different than the region of interest **202(2)** of the proximity sensors.

FIG. **11**A illustrates an example cross-sectional view of an item-identifying cart **1000** that includes the imaging device **702(6)** for identifying items **806** placed in the cart **1000**. Again, the cart **1000** may include the proximity sensors and corresponding functionality as described above with reference to the cart **804**. While this cart **1000** may have a different form factors than other carts illustrated and described herein, characteristics of the cart **1000** may be applied to the other cart form factors, and vice versa. As illustrated, the cross-section of the cart **1000** is taken along a plane defined by the x-axis and y-axis along the center of the cart **1000** from the back to the front of the cart **1000**. In some examples, the imaging device **702(6)** is positioned with an optical axis **1004** and an FOV **1006** oriented downwards from the handle and towards a storage location underneath the handle and adjacent the basket of the cart **1000**.

FIG. **11**B illustrates another example perspective view of an item-identifying cart **1000** and shows the region of interest **202(1)** defined by the imaging devices **702(5)** and **702(6)**. The region of interest **202(1)** may comprise a volumetric, three-dimensional (3D) shape in which items **806** are captured in image data of the cameras, and/or detected by proximity sensors. Thus, the region of interest **202(1)** defines a volumetric region in which at least one of the cameras in a capture assembly is able to capture image data representing an item **806**. that has imaging devices **834** for identifying items **806** placed into a storage location of the cart **1000** residing beneath the handle.

FIG. **12** illustrates another example of an item-identifying cart **1000**, including a top view and a cross sectional view **1202**, that has item carriers **1204** placed inside the basket of the cart **1000**, and imaging devices **834** and light sources **902** (within respective capture assemblies) that are used to identify an item being placed in the item carriers **1204**.

As illustrated by the top view, the cart **1000** may include a basket that is sized to store one or more item carriers **1204**, such as bags (e.g., plastic bags, paper bags, etc.), boxes, user-provided item carrier, and/or any other item carrier. In some examples, the cart **1000** may have a basket **826** that is sized to efficiently fit (e.g., minimize empty space in the basket **826**) one or more of the item carriers **1204**. As shown in the cross-sectional view of the basket **826** of the cart, the item carriers **1204** may be sized such that the tops of the item carriers **1204(1)** and **1204(2)** are below the perimeter defining the top of the basket **826**. In this way, the FOVs of the imaging devices **834** are not obstructed by the item carriers **1204**.

As shown, the item carriers **1204** may have items **806** stored therein, which are no longer visible to cameras due to their placement in the item carriers **1204**. Accordingly, if the imaging devices **834** had FOVs **1006** that generated image data of the interior of the basket **826**, the items **806** may not be visible due to occlusion from the item carriers **1204**. However, to identify the items **806** placed in a cart **1000**, the imaging devices **834** need to be able to view the items **806**, which would prevent users **808** from being able to place item carriers **1204** in their carts **804**. Thus, by having FOVs **1006** that at least partly face upward relative to the top of the perimeter of the basket **826**, the items **806** that are placed in the basket are identifiable in image data generated by the imaging devices **834**. Additionally, users **808** are able to place their item carriers **1204** directly in the basket **826** to receive items **806** as the user **808** shops, thereby reducing friction in the traditional-checkout experience by having to take items out of the cart **1000** to be bagged or otherwise placed in item carriers **1204**.

In some examples, the basket **826** (or other location on the cart **1000**) may include one or more hooks to help support the item carriers **1204**. For instance, the item carriers **1204** may be a cloth, or other material, with handles or holes. To help hold the item carriers **1204** open and/or up, the basket **826** may include hooks near the top or perimeter and/or hooks on the outside of the basket **826** to hook into holes of the item carriers **1204** and/or to hold up handles of the item carriers **1204**, such as the bag clips **808(1)-(2)** discussed above.

FIG. **13** illustrates example components of an item-identifying cart **1300** configured to support at least a portion of the functionality of a cart management system. In some instances, the cart **1300** may correspond to and/or include some or all of the functionality of the carts described above.

The cart **1300** may include one or more hardware processors **1302** (processors) configured to execute one or more stored instructions. The processors **1302** may comprise one or more cores. The cart **1300** may include one or more input/output (I/O) interface(s) **1304** to allow the processor **1302** or other portions of the cart **1300** to communicate with other devices. The I/O interfaces **1304** may comprise Inter-Integrated Circuit (I2C), Serial Peripheral Interface bus (SPI), Universal Serial Bus (USB) as promulgated by the USB Implementers Forum, and so forth. The I/O interfaces **1304** may allow the various modules/components to communicate with each other and/or control each other.

The cart **1300** may also include one or more communication interfaces **1306**. The communication interfaces **1306** are configured to provide communications between the cart **1300** and other devices, such as the server(s) **820**, sensors, interface devices, routers, and so forth. The communication interfaces **1306** may include devices configured to couple to personal area networks (PANs), wired and wireless local area networks (LANs), wired and wireless wide area networks (WANs), and so forth. For example, the communication interfaces **1306** may include devices compatible with Ethernet, Wi-Fi™, and so forth. The cart **1300** may also include one or more busses or other internal communications hardware or software that allow for the transfer of data between the various modules and components of the cart **1300**.

The cart **1300** may also include the one or more imaging devices **834**, such as the first imaging device **834(1)** for identifying a user operating the cart and one or more second imaging devices **834(2)**-(N) and/or **310** for identifying items placed into and removed from a basket of the cart. The cart **1300** may further include the light sources **902**, the lighting elements **840**, and the weight sensors **906** described above.

In some instances, the cart **1300** further includes include one or more proximity sensors **1310**. The proximity sensors **1310** may comprise any type of sensor that is able to detect the presence of nearby objects without the need for physical contact (e.g., ToF sensors, PIR sensors, infrared sensors, capacitive sensors, ultrasonic sensors, etc.). As described above, each proximity sensor may be configured to output an indication when the respective proximity sensor detects an object within a threshold distance of the sensor. Further, the configured threshold distances may vary from sensor to sensor in order to collectively create the virtual perimeter **308**, discussed above with reference to FIG. **3**D. Further, in some instances a single proximity sensor may be configured with multiple threshold distances. For instance, in the example of a proximity sensor having 64 diodes, the senor may be effectively split into quadrants of sixteen sensors such that each quadrant is configured to output an indication when an object is detected at a threshold distance that is potentially unique to the other three quadrants. For instance, a distance of a closest object of each diode of the sixteen diodes in a particular quadrant may be averaged and this average distance may be compared to a threshold to determine whether to output an indication that an object has been detected.

The imaging devices, meanwhile, may comprise any type of camera or imaging device configured to generate image data (and/or video data) or information descriptive of a plurality of picture elements or pixels. Additionally, in some instances the cart **1300** may include one or more imaging devices that are outward-facing and that generate image data representing the facility **802** around the cart **1300**.

The cart **1300** may include one or more power supply(ies) **1314** to provide power to the components of the cart **1300**, such as the battery pack module **838**. The power supply(ies) **1314** may also include a secondary (e.g., internal) power supply **1318** to allow for hot swapping of battery pack modules **838**, such as one or more capacitors, internal batteries, etc.

The cart **1300** may also include a display **836** configured to display image data, such as pictures, videos, user interface elements, and/or any other image data. The display **836** may comprise any type of display **836**, and may further be a touch screen to receive touch input from a user. The cart **1300** may also include one or more microphones **1320** and one or more loudspeakers **1322** to facilitate a dialogue with a user **808**, and/or to receive feedback from the user **808**. The microphone(s) **1320** may capture sound representing the user's speech, and the loudspeaker(s) **1322** may output machine-generated words to facilitate a dialogue, prompt a user **808** for feedback on an item **806** and/or for other information, and/or output other alerts or notifications.

The cart **1300** may include one or more memories **1324**. The memory **1324** comprises one or more computer-readable storage media (CRSM). The CRSM may be any one or more of an electronic storage medium, a magnetic storage medium, an optical storage medium, a quantum storage medium, a mechanical computer storage medium, and so forth. The memory **1324** provides storage of computer-readable instructions, data structures, program modules, and other data for the operation of the cart **1300**. A few example functional modules are shown stored in the memory **1324**, although the same functionality may alternatively be implemented in hardware, firmware, or as a system on a chip (SOC).

The memory **1324** may include at least one operating system (OS) component **526**. The OS component **1326** is configured to manage hardware resource devices such as the I/O interfaces **1304**, the communication interfaces **1306**, and provide various services to applications or components executing on the processors **1302**. The OS component **1326** may implement a variant of the FreeBSD™ operating system as promulgated by the FreeBSD Project; other UNIX™ or UNIX-like variants; a variation of the Linux™ operating system as promulgated by Linus Torvalds; the Windows® Server operating system from Microsoft Corporation of Redmond, Washington, USA; and so forth.

One or more of the following components may also be stored in the memory **1324**. These components may be executed as foreground applications, background tasks, daemons, and so forth. A communication component **1328** may be configured to establish communications with one or more of the sensors, one or more of the servers **820**, or other devices. The communications may be authenticated, encrypted, and so forth.

The memory **1324** may further store a cart management system **1330**. The cart management system **1330** is configured to provide the item-identifying functions (and other functions) provided by the cart **1300** as described herein. For example, the cart management system **1330** may be configured to identify a user operating a cart, identify items **806** placed into the cart, and maintain a virtual shopping cart for a user **808** of the cart **1300**. While these components are described as operating on the cart **1300**, in some instances some or all of these components reside additionally or alternatively on the servers **820** or elsewhere.

The cart management system **1330** may include a user-activation component **1332** that performs operations for activating a shopping session using a cart **1300** on behalf of a user **808**. For instance, a user **808** may have previously registered for a user account with an operator of the facility to utilize various automated management services provided by an operator of the facility **802**. The user **808** may have registered for a user account, such as by providing user data **1352**, to automate payments made for items taken by the user and included a payment means (e.g., credit card, bank account number, etc.), and may have also provided an identification means in the user data **1352** to the user-activation component **1332** such that the cart **1300** can recognize the user **808**. For instance, the user **808** may have registered to identify themselves to the cart **1300** using any identification technique by the user-activation component **1332**, such as by providing user data **1352** by presenting an identification means to the first imaging device **834**(**1**) (e.g., presenting a driver's license, presenting a facility-issued card, presenting a user identifier via a mobile phone, etc.), speaking a predefined utterance that is captured by the microphone(s) (e.g., a name of the user, a predefined keyword, etc.), and/or looking into a camera for facial recognition. Once a user **808** has identified themselves to using the user-activation component **1332**, the user-activation component **1332** may open a shopping session where the cart **1300** identifies and track items **806** retrieved by the user **808** and placed in the cart **1300**.

The cart management system **1330** may additionally include an activity-detection component **1334** configured to detect items **806** (or objects) within a particular proximity to the cart. For example, one or more proximity sensor(s) **1310** may generate sensor data **1354** that indicates a distance between the proximity sensor(s) **1310** and any objects located in the FOV of the proximity sensor(s). The activity-detection component **1334** may analyze the sensor data **1354** and determine if an object is within a threshold distance indicating that the object is near the cart **1300** and/or within or near the perimeter of the top of the basket **826** of the cart **1300** (e.g., one foot from the proximity sensor(s), two feet from the proximity sensor(s), etc.). In this way, the proximity sensor(s) may generate sensor data **1354** that indicates whether or not an item **806** is being moved in or out of the basket **826** of the cart **1300**. However, in some examples, rather than using sensor data **1354** generated by a proximity sensor(s), the activity detection component **1334** may utilize image data **1356** generated by the imaging devices **834**(**2**)-(N) to determine if an object is within a threshold distance from the cart **1300**.

The cart management system **1330** may further include a strobing component **1336** configured to cause the light sources **902** and/or shutters of the imaging devices **834** to strobe according to different frequencies. As noted above, the light sources **902** may emit light in any light spectrum (e.g., infrared, near infrared, visible, etc.). However, some items **806** may have text and/or other marking printed thereon using dye-based color inks that have diminished and/or similar near infrared (NIR) absorbance. This may lead to compromised contrast between, and essentially "washing out" of many distinct features in the visible spectrum when viewed in NIR. Accordingly, in some examples it may be advantageous to cause the light sources **902** to emit light in the visible spectrum. When generating image data **1356** using the imaging devices **834**, motion blur may appear when capturing fact moving objects. However, the motion blur may be reduced or eliminated by exposing the imaging device's imager for a short (e.g., sub-millisecond) durations. Accordingly, the strobing component **1336** may strobe the opening and closing of shutters of the imaging devices **834** to limit the sensor exposure duration. Additionally, the strobing component **1338** may cause the LEDs to emit/strobe light at a particular frequency, as discussed further with respect to FIG. **10**. In some instances, the strobing component **1338** may cause the LEDs to strobe at a first rate (e.g., 8200 hertz) prior to detecting predefined activity, such as a user placing an item into or removing an item from a cart, while causing the LEDs to strobe at a second, different rate (e.g., 60 hertz) upon identifying the predefined activity. Further, the LEDs may emit light in the visible range in some instances, and in the non-visible range in other instances. In some examples, the LEDs may comprise RGB LEDs that may be mixed according to different respective levels to tune a resulting color of the LEDs.

The cart management system **1330** may also include an item-identification component **1338** configured to analyze image data **1356** to identify an item **806** represented in the image data **1356**. The image data **1356** may comprise information descriptive of a plurality of picture elements, or pixels, for one or more image frames (e.g., a still picture, multiple picture frames, video frames, etc.). The item-identification component **1338** may analyze the image data **1356** using various image processing techniques, or computer vision techniques. For instance, the item-identification component **1338** may extract a representation of an item **806** depicted in the image data **1356** generated by at least one imaging device **834**. The representation may include identifying text printed on the item **806**, colors or color schemes printed in the item, determining 2-D and/or 3D shapes of the items **806**, and/or other techniques for extract a representation of the item **806**. In some instances, the representation of the item **806** depicted in the image data **1356** may comprise a numeric representation, such as a feature vector or a set of feature vectors.

In some examples, a data store **1350** stored in the memory **1324** may include item data **1358**, which may include representations of the items **806** offered for acquisition at the facility **802**. The item-identification component **1338** may compare the extracted represented of the item **806** with the "gallery" or stored representations of the known items **806** in the item data **1358**. In some instance, the item representation may include an indication of a barcode or SKU data for the item **806** as recognized in, or extracted from, the image data **1356**. The item-identification component **1338** may determine confidence level data **1362** based on the comparisons with item representation in the item data **1358**. The item-identification component **1338** may determine, and assign, confidence levels indicating how likely it is that the item **806** represented in the image data **1356** corresponds to an item from the item gallery in the item data **1358**. Based on the confidence level data **1362**, the item-identification component **1338** may determine an item identifier **1370** for the item in the image data **1356** (or multiple item identifiers **1370**) that corresponds to an item in the item data **1358** to which the item **806** corresponds.

In some examples, the data store **1350** may include physical-layout data **1374** that is used by the item-identification component **1338** to determine the item **806**. The physical-layout data **1374** may include or provide a mapping of physical locations within the physical layout of devices and objects such that the location of the cart **1300** may be utilized to determine an item **806** stored nearby. The physical-layout data **1374** may indicate the coordinates within the facility **802** of an inventory location **812**, items **806** stored at that inventory location **812**, and so forth. In examples where the cart **1300** has location determining sensors (e.g., GPS, RFID, proximity, etc.), the location sensor data may be used to determine where in the store the user **808** is. In such examples, the item-identification component **1338** may access the physical-layout data **1374** to determine if a location associated with the event is associated with items **806**, and confidence levels for the corresponding representations of items in the item data **1358**. Continuing the example above, given the location within the facility **802** of the event and image camera data, the physical-layout data **1374** may determine the items **806** that may have been represented in generated images of the event **810**.

The cart management system **1330** may further include an event-determination component **1340** to determine event-description data **1360** for the item **806** in the image data **1356**. The event-determination component **1340** may determine if the user **808** is adding an item **806** to the cart **1300**, removing the item from the cart **1300**, etc., based on movement of the item **806** and/or whether the item is shown in the image data **1356**. For instance, if the item **806** is shown as being moved downward towards the interior of the cart **1300**, and the user's hand then leaves the basket without the item, **106** it can be determined that the user **808** added the item **806** to the cart **1300**. Similarly, if the user's hand **808** moves into the cart without an item **806** and is depicted in the image data **1356** taking an item **806** from the cart, the event-determination component **1340** may determine that the user **808** removed an item **806** from the cart **1300**.

The cart management system **1330** may also include a virtual-cart management component **1342** configured to manage virtual shopping cart data **1368** for the cart **1300**. For instance, the virtual-cart management component **1342** may utilize the item data **1358**, event-description data **1360**, and confidence level data **1362** to add item identifier(s) **1370** to the virtual shopping cart data **1368** for items **806** that were added to the cart **1300**, remove item identifier(s) **1370** from the virtual shopping cart data **569** for items **806** that were removed from the cart **1300**, and track item quantity data **1372** indicating quantities of particular items **806** in the cart **1300**.

The cart management system **1330** may further include a user-interface component **1344** configured to present user interfaces on the display **836** based on user-interface data **1376**. The user interfaces **1376** may include one or more fields to present data, and/or receive touch input (or other input via a keyboard, mouse, etc.) from a user **808**. For instance, if the item-identification component **1338** is unable to determine an item identifier **1370** for an item **806** shown in the image data **1356**, the user-interface component **1344** may receive inquiry data **1364** generated by an inquiry component **1346** to prompt a user **808** for feedback to help identify the item **806**, and/or other information (e.g., if multiple items were placed in the cart **1300**). The inquiry component **1346** may be configured to generate inquiry data **1364** based on the information needed to identify the item **806**. For instance, the inquiry data **1364** may include a prompt to request particular feedback from the user **808**, such as to provide input (e.g., touch input, vocal/utterance input, etc.) to identify the item **806**, input to indicate how many items **806** were added to the cart, input to indicate whether an item **806** was removed or added, etc. In some examples, the user-interface component **1344** may present one or more images depicting items from the item data **1358** that have the highest confidence levels as corresponding to the item **806** in the image data **1356**, but confidence levels that are not high enough to make a final decision as to the item **806**. For instance, the user-interface component **1344** may present pictures of two different items that have high confidence levels **1362** and request that the user **808** select or indicate the appropriate item **806**. Additionally, or alternatively, the user-interface component **1344** may present user-interface data **1376** that prompts the user for feedback regarding whether or not the item **806** was added to, or removed from the cart **1300**. The received response may be stored as response data **1366**.

In some examples, the cart management system **1330** may further include a locating component **1378** configured to determine locations of the cart **1300** in the facility **802**. For instance, the locating component **1378** may analyze sensor data **1354** collected by sensors of the cart **1300** to determine a location. In some examples, the communication interface(s) **1306** may include network interfaces that configured the cart **1300** to receive or detect wireless signals (e.g., WiFi signals, Bluetooth signals, etc.) and generate sensor data **1354** indicative of the signals. The locating component **1378** may analyze the sensor data **1354** using various techniques to identify the location of the cart **1300**, such as WiFi triangulation, received signal strength indicators (RSSI), and/or other methods for analyzing wireless signals to determine a location of the cart **1300**. In some instances, the facility **802** may include various infrared (IR) or near-IR emitters at different locations that emit light according to frequencies, patterns, etc. that indicate the different locations in the facility **802**. In such examples, the cart **1300** may include a light sensor to generate the sensor data **1354** representing the IR or NIR and determine the location of the cart **1300** in the facility. In some instances, there may be visible landmarks or markers throughout the facility that indicate a location in the facility, and the locating component **1378** may analyze image data **1356** generated by an outward facing camera to determine a location of the cart **1300**. As another example, there may be various radio frequency (RF) emitters positioned throughout the store, and the cart **1300** may include an RF receiver to allow the locating component **1378** to perform IR beaconing to determine the location of the cart **1300**. The locating component **1378** may perform one, or any combination, of the above techniques to determine a location of the cart **1300** in the facility and/or any other technique known in the art.

The locating component **1378** may perform various operations based on determining the location of the cart **1300** within the facility **802**. For instance, the locating component **1378** may cause user interface data **1376** to be presented on the display **836** that includes a map of the facility **802** and/or directions to an item **806** for the user of the cart **1300**. Additionally, or alternatively, the locating component **1378** may utilize the location of the cart, the physical-layout data **1374**, and/or item data **1358** and "push" user interfaces to the display **836** that indicate various location-based information, such as indications of deals for items **806** located nearby, indications of items **806** located nearby and on the user's shopping list, and/or other user interface data **1376**.

In some examples, the cart management system **1330** may further include a power-saving component **1380** configured to selectively power off or down one or more components of the cart **1300** when the cart **1300** determines that no users are within a threshold distance of the cart **1300**. For example, the power-saving component **1380** may be configured to determine when a user is not within a threshold distance and, in response, may instruct one or more components of the cart **1300** to power off or otherwise lessen the power the components consume from the batter(ies) **1316**. For example, the power-saving component may instruct the item-identification component **1338** and/or the event-determination component **1340** to stop performing image-processing on the image data **1356** generated by the imaging devices **834** or may instruct these components to perform the image-processing at a lesser frame rate. Additionally, or alternatively, the power-saving component may instruct the user-activation component **1332** or the activity-detection component **1334** to refrain from performing image-processing on the image data **1356** or lessen the frame rate at which these components perform the image-processing. In addition, or in the alternative, the power-saving component **1380** may instruct any of the other components of the cart management system **1330** to power off or down in order to consume less power in response to determining that a user is not within the threshold distance of the cart **1300** (e.g., within the virtual perimeter **308** of FIG. 3D), and/or may instruct any other software and/or firmware components of the cart **1300** to power off or down in response.

In addition, or in the alternative, the power-saving component **1380** may instruct one or more hardware components of the cart **1300** to power off or down in response to determining that a user is not within the threshold distance of the cart **1300**. For instance, the power-saving component **1380** may instruct the imaging devices **834** to power off or lessen a frame rate at which the imaging components **834** generate the image data. Additionally, or alternatively, the power-saving component **1380** may instruct the display **836** to power off (or dim its brightness) and/or may instruct the light sources **902**, lighting elements **840**, weight sensors **906** (and/or weight-sensing firmware/software), the communication interfaces **1306**, I/O interfaces **1304**, the microphones **1320**, the loudspeakers **1322**, and/or any other hardware component of the cart **1300** to power off or otherwise consume less power from the batter(ies) **1316**. Furthermore, in addition to power off or down any of these software, firmware, and/or hardware components of the cart **1300**, the power-saving component **1380** may be configured to power on or up each of these components in response to determining that a user is within the threshold distance of the cart **1300** (e.g., within the example virtual perimeter **308**).

The power-saving component **1380** may determining whether a user is within the threshold distance of the cart **1300** based on proximity data **1382** generated by the proximity sensors **1310**. For instance, the power-saving component **1380** may receive the proximity data **1382** and analyze the proximity data to determine whether a user is within the threshold distance. In some instances, the proximity data **1382** indicates, for each sensor or quadrant (or the like) of a sensor, the distance to a closest user or other object. Thus, the power-saving component **1380** may determine whether the closest user/object is within the threshold distance and, if not, may send the instruction(s) for causing the component (s) to lessen their consumed power. Further, in some instances, the power-saving component **1380** may input the proximity data **1380** and/or additional sensor data generated at the same/similar time as the subject proximity data (e.g., image data **1356**, accelerometer data, etc.) into one or more trained models **1384** for determining whether or not the object within the threshold distance of the cart corresponds to a user. If the trained model indicates that the object (or each object) detected by the proximity sensors **1310** does not correspond to a user, but rather an inanimate object (e.g., a rack in the facility), then the power-saving component **1380** may send the instruction(s) to lessen power consumed by the component(s) even if one or more (non-user) objects are detected within the threshold distance of the cart. It is to be appreciated that the trained model(s) may be trained as described above, by inputting training data in the form of labelled results (user, no user) and corresponding sensor data into the model during the training process. Of course, while one example is provided, the model(s) **1384** may be trained in any other manner.

In addition, while the above example describes the proximity sensors **1310** outputting proximity data **1382** indicating the distance to a nearest object, in some instances the proximity sensors may output an indication when an object is within a threshold distance but not otherwise. For instance, a first proximity sensor may be configured to output an indication in response to detecting an object within one foot, while another proximity sensor (or quadrant of the same proximity sensor) may be configured to output an indication in response to detecting an object within two feet. Thus, these proximity sensors may output the respective indications in response to detecting an object within their respective threshold distances, but otherwise may refrain from outputting data to the power-saving component **1380**. Thus, the power-saving component **1380** may cause the component(s) to power off and/or down based on not receiving an indication of an object within a threshold distance from the proximity sensors **1310** for a threshold amount of time. In addition, the power-saving component **1380** may cause the component(s) to power off and/or down in response to receiving an indication that each object detected by a proximity sensor **1310** within a threshold distance within a certain amount of time does not correspond to a user, as determined by the trained model(s) **1384**.

FIG. **14** illustrates example components of server computing devices **106** for generate models for use by mobile carts to detect activity represented by image data generated by cameras of the respective mobile carts. As illustrated, the server computing devices **106** may include one or more hardware processors **1402** and memory **1404**, which may store the verification component **134**, the retraining component **136**, the model-testing component **138**, and a model-update component **1406**. As discussed above, the verification component **134** may function to re-analyze each received hard negative **130** and hard positive **132** to determine whether the activity-detection component **118** correctly labeled each of these frames. For instance, the verification component **134** may re-analyze the image data **142** associated with each of these frames to determine whether they include activity or not.

To aid in this analysis, the servers **106** may further store an object-depth component **1408**, a product-localization component **1410**, a barcode-localization component **1412**, a body-part detection component **1414**, and a reader component **1416**. The object-depth component **1408** may analyzing the image data **142** to determine whether the image data (e.g., a particular frame of image data corresponding to a potential hard negative or positive) includes an object **1418** and, if so, the 3D depth of the object. The component **1408** may then determine whether this object **1418** is within a 3D volume of a region-of-interest **202(1)** or **202(2)**. The product-localization component **1410**, meanwhile, may analyze frame(s) of image data to determine whether the frame(s) include a product **1420** offered in an inventory of a facility, while the body-part detection component **1414** may analyze frame(s) of image data to determine whether the frame(s) include a body part and the barcode-localization component **1412** and the reader component **1416** may analyze frame(s) of image data to determine whether the frame(s) include a barcode **1422** and, if so, the value of the barcode **1422**. As will be appreciated, the object-depth component **1408**, the product-localization component **1410**, the barcode-localization component **1412**, the body-part detection component

1414, and the reader component 1416 may each use one or more trained machine-learning models 140 to make their respective determinations.

Further, and as discussed above, the verification component 134 may analyze the rules data 144 to determine whether or not to label a particular image frame as including activity based on information such as whether the particular image frame includes an object 1418, a product 1420, a barcode 1422, and/or a body part of a user. The rules data 144 may store any number of rules regarding whether a frame is to be labeled as including activity based on the resulting analysis of the image frame. For instance, the rules data 144 may include a rule indicating that a frame that includes an object in the region of interest is to be labeled as representing activity, that an image frame that includes a body part is to be labeled as representing activity, that an image frame that includes a barcode or item is to be labeled as representing activity, and/or so forth.

Upon the verification component 134 determining that the activity-detection component 118 of the mobile cart has correctly labeled a particular hard positive or hard negative, the verification component 134 may discard or filter out this image frame. That is, the servers 106 may determine that the cart 104 accurately identified what was presumed as a discrepancy and, thus, that data point might not be used to re-train the model in some instances. In instances where the verification component 134 determines that the activity-detection component 118 of the mobile cart has incorrectly labeled a particular hard positive or hard negative, the verification component 134 may re-label this frame and store this re-labeled frame as training data 146 for use in re-training the model(s) 140. The re-training component 136 may then use the training data 146 to re-train the model(s) 140, which now include the correctly labeled hard negatives 130 and hard positives 132. The re-training component 136 may generate a new model based on the re-training of an existing model using the now-supplemented training data 146.

After a new model 140 has been generated, the model-testing component 138 may determine whether the new model is more accurate than the model(s) currently being used by the cart 104 and/or other carts. To do so, the model-testing component 138 may apply the newly generated model 140 to test data 148 that is associated with known and accurate labels to determine an accuracy or efficacy of the model. Upon determining this accuracy or efficacy, the model-testing component 138 may determine whether this accuracy or efficacy is greater than an accuracy or efficacy of the model 120 currently being used by the cart 104 and/or other mobile carts. If so, then the model-update component 1406 may, upon some trigger event, send the newly generated model to the cart 104 and/or other carts for use by the activity-detection component 118. For instance, the model-update component 1406 may send the new model 140 to carts on a periodic basis (e.g., nightly), in response to receiving a request from an operator of the system, or the like. Using the new model 140, the activity-detection component 118 may thus be more accurate in labeling frames as including activity or not and, thus, the activity-smoothing component 122 may be more accurate in identifying activity windows and no-activity windows.

Embodiments may be provided as a software program or computer program product including a non-transitory computer-readable storage medium having stored thereon instructions (in compressed or uncompressed form) that may be used to program a computer (or other electronic device) to perform processes or methods described herein. The computer-readable storage medium may be one or more of an electronic storage medium, a magnetic storage medium, an optical storage medium, a quantum storage medium, and so forth. For example, the computer-readable storage media may include, but is not limited to, hard drives, floppy diskettes, optical disks, read-only memories (ROMs), random access memories (RAMs), erasable programmable ROMs (EPROMs), electrically erasable programmable ROMs (EEPROMs), flash memory, magnetic or optical cards, solid-state memory devices, or other types of physical media suitable for storing electronic instructions. Further, embodiments may also be provided as a computer program product including a transitory machine-readable signal (in compressed or uncompressed form). Examples of machine-readable signals, whether modulated using a carrier or unmodulated, include, but are not limited to, signals that a computer system or machine hosting or running a computer program can be configured to access, including signals transferred by one or more networks. For example, the transitory machine-readable signal may comprise transmission of software by the Internet.

Separate instances of these programs can be executed on or distributed across any number of separate computer systems. Thus, although certain steps have been described as being performed by certain devices, software programs, processes, or entities, this need not be the case, and a variety of alternative implementations will be understood by those having ordinary skill in the art.

Additionally, those having ordinary skill in the art readily recognize that the techniques described above can be utilized in a variety of devices, environments, and situations. Although the subject matter has been described in language specific to structural features or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described. Rather, the specific features and acts are disclosed as exemplary forms of implementing the claims.

While the foregoing invention is described with respect to the specific examples, it is to be understood that the scope of the invention is not limited to these specific examples. Since other modifications and changes varied to fit particular operating requirements and environments will be apparent to those skilled in the art, the invention is not considered limited to the example chosen for purposes of disclosure and covers all changes and modifications which do not constitute departures from the true spirit and scope of this invention.

Although the application describes embodiments having specific structural features and/or methodological acts, it is to be understood that the claims are not necessarily limited to the specific features or acts described. Rather, the specific features and acts are merely illustrative some embodiments that fall within the scope of the claims of the application.

What is claimed is:

1. A method comprising: receiving, at a computing device, a first frame of image data generated by one or more cameras of a mobile cart;

receiving, at the computing device, first data indicating that the first frame was determined, by a first machine-learning model operating on the mobile cart, to not represent a predefined activity indicating a user interaction in a region of interest;

receiving, at the computing device, second data indicating that the first frame is associated with a time window that was determined to represent the predefined activity, the time window associated with at least a second frame of image data that was determined by the first machine-learning model to represent the predefined activity;

analyzing the first frame;

determining, based at least in part on the analyzing, that the first frame represents the predefined activity;

determining a first efficacy rate of the first machine-learning model, the first efficacy rate based at least in part on applying the first machine-learning model to labeled test data;

generating a second machine-learning model based at least in part on the first frame and a label indicating that the first frame represents the predefined activity;

applying the second machine-learning model to the labeled test data to determine a second efficacy rate associated with the second machine-learning model;

determining that the second efficacy rate is greater than the first efficacy rate;

and sending, to the mobile cart, the second machine-learning model in response to determining that the second efficacy rate is greater than the first efficacy rate.

2. The method as recited in claim **1**, wherein:

the analyzing comprises analyzing the first frame to determine that the first frame represents an object within a three-dimensional (3D) volume associated with a basket of the mobile cart; and

the determining comprises determining that the first frame represents the predefined activity based at least in part on the analyzing the first frame to determine that the first frame represents the object within the 3D volume associated with the basket.

3. The method as recited in claim **1**, wherein:

the analyzing comprises analyzing the first frame to determine that the first frame represents a body part of a user; and

the determining comprises determining that the first frame represents the predefined activity based at least in part on the analyzing the first frame to determine that the first frame represents the body part of the user.

4. The method as recited in claim **1**, wherein:

the analyzing comprises analyzing the first frame to determine that the first frame represents at least one of a product, a barcode, or text; and

the determining comprises determining that the first frame represents the predefined activity based at least in part on the analyzing the first frame to determine that the first frame represents the at least one of the product, the barcode, or the text.

5. The method as recited in claim **1**, wherein the time window comprises a first time window, and further comprising:

sending the second machine-learning model to the mobile cart;

receiving, at the computing device, a third frame of image data generated by the one or more cameras of a mobile cart;

receiving, at the computing device, third data indicating that the third frame was determined, by the second machine-learning model operating on the mobile cart, to represent a predefined activity;

receiving, at the computing device, fourth data indicating that the third frame is associated with a second time window that was determined to not represent the predefined activity, the second time window associated with at least a fourth frame of image data that was determined by the second machine-learning model to not represent the predefined activity;

analyzing the third frame;

determining, based at least in part on the analyzing of the third frame, that the third frame does not represent the predefined activity; and

generating a third machine-learning model based at least in part on the third frame and a label indicating that the first frame does not represent the predefined activity.

6. The method as recited in claim **1**, further comprising: determining a triggering event; and sending the second machine-learning model to the mobile cart in response to determining the triggering event.

7. A computing device: one or more processors; and one or more memory storing computer-readable instructions that, upon execution by the one or more processors, configure the computing device to: receiving, at a computing device, a first frame of image data generated by one or more cameras of a mobile cart;

receiving, at the computing device, first data indicating that the first frame was determined, by a first machine-learning model operating on the mobile cart, to not represent a predefined activity indicating a user interaction in a region of interest;

receiving, at the computing device, second data indicating that the first frame is associated with a time window that was determined to represent the predefined activity, the time window associated with at least a second frame of image data that was determined by the first machine-learning model to represent the predefined activity;

analyzing the first frame;

determining, based at least in part on the analyzing, that the first frame represents the predefined activity;

determining a first efficacy rate of the first machine-learning model, the first efficacy rate based at least in part on applying the first machine-learning model to labeled test data;

generating a second machine-learning model based at least in part on the first frame and a label indicating that the first frame represents the predefined activity;

applying the second machine-learning model to the labeled test data to determine a second efficacy rate associated with the second machine-learning model;

determining that the second efficacy rate is greater than the first efficacy rate;

and sending, to the mobile cart, the second machine-learning model in response to determining that the second efficacy rate is greater than the first efficacy rate.

8. The computing device of claim **7**, wherein:

the analyzing comprises analyzing the first frame to determine that the first frame represents an object within a three-dimensional (3D) volume associated with a basket of the mobile cart; and

the determining comprises determining that the first frame represents the predefined activity based at least in part on the analyzing the first frame to determine that the first frame represents the object within the 3D volume associated with the basket.

9. The computing device of claim **7**, wherein:

the analyzing comprises analyzing the first frame to determine that the first frame represents a body part of a user; and

the determining comprises determining that the first frame represents the predefined activity based at least in part on the analyzing the first frame to determine that the first frame represents the body part of the user.

10. The computing device of claim 7, wherein:

the analyzing comprises analyzing the first frame to determine that the first frame represents at least one of a product, a barcode, or text; and

the determining comprises determining that the first frame represents the predefined activity based at least in part on the analyzing the first frame to determine that the first frame represents the at least one of the product, the barcode, or the text.

11. The computing device of claim 7, wherein the time window comprises a first time window, and wherein the computing device is further configured to:

send the second machine-learning model to the mobile cart;

receive, at the computing device, a third frame of image data generated by the one or more cameras of a mobile cart;

receive, at the computing device, third data indicating that the third frame was determined, by the second machine-learning model operating on the mobile cart, to represent a predefined activity;

receive, at the computing device, fourth data indicating that the third frame is associated with a second time window that was determined to not represent the predefined activity, the second time window associated with at least a fourth frame of image data that was determined by the second machine-learning model to not represent the predefined activity;

analyze the third frame;

determine, based at least in part on the analyzing of the third frame, that the third frame does not represent the predefined activity; and

generate a third machine-learning model based at least in part on the third frame and a label indicating that the first frame does not represent the predefined activity.

12. The computing device of claim 7, to the computing device is further configured to: determine a triggering event; and send the second machine-learning model to the mobile cart in response to determining the triggering event.

13. One or more non-transitory computer-readable storage media storing instructions that, upon execution on a computing device, cause the computing device to perform operations comprising:

receiving, at a computing device, a first frame of image data generated by one or more cameras of a mobile cart;

receiving, at the computing device, first data indicating that the first frame was determined, by a first machine-learning model operating on the mobile cart, to not represent a predefined activity indicating a user interaction in a region of interest;

receiving, at the computing device, second data indicating that the first frame is associated with a time window that was determined to represent the predefined activity, the time window associated with at least a second frame of image data that was determined by the first machine-learning model to represent the predefined activity;

analyzing the first frame;

determining, based at least in part on the analyzing, that the first frame represents the predefined activity;

determining a first efficacy rate of the first machine-learning model, the first efficacy rate based at least in part on applying the first machine-learning model to labeled test data;

generating a second machine-learning model based at least in part on the first frame and a label indicating that the first frame represents the predefined activity;

applying the second machine-learning model to the labeled test data to determine a second efficacy rate associated with the second machine-learning model;

determining that the second efficacy rate is greater than the first efficacy rate;

and sending, to the mobile cart, the second machine-learning model in response to determining that the second efficacy rate is greater than the first efficacy rate.

14. The one or more computer-readable storage media of claim 13, wherein:

the analyzing comprises analyzing the first frame to determine that the first frame represents an object within a three-dimensional (3D) volume associated with a basket of the mobile cart; and

the determining comprises determining that the first frame represents the predefined activity based at least in part on the analyzing the first frame to determine that the first frame represents the object within the 3D volume associated with the basket.

15. The one or more computer-readable storage media of claim 13, where:

the analyzing comprises analyzing the first frame to determine that the first frame represents a body part of a user; and

the determining comprises determining that the first frame represents the predefined activity based at least in part on the analyzing the first frame to determine that the first frame represents the body part of the user.

16. The one or more computer-readable storage media of claim 13, wherein:

the analyzing comprises analyzing the first frame to determine that the first frame represents at least one of a product, a barcode, or text; and

the determining comprises determining that the first frame represents the predefined activity based at least in part on the analyzing the first frame to determine that the first frame represents the at least one of the product, the barcode, or the text.

17. The one or more computer-readable storage media of claim 13, wherein the time window comprises a first time window, and wherein the operations further comprise:

sending the second machine-learning model to the mobile cart;

receiving, at the computing device, a third frame of image data generated by the one or more cameras of a mobile cart;

receiving, at the computing device, third data indicating that the third frame was determined, by the second machine-learning model operating on the mobile cart, to represent a predefined activity;

receiving, at the computing device, fourth data indicating that the third frame is associated with a second time window that was determined to not represent the predefined activity, the second time window associated with at least a fourth frame of image data that was determined by the second machine-learning model to not represent the predefined activity;

analyzing the third frame;

determining, based at least in part on the analyzing of the third frame, that the third frame does not represent the predefined activity; and

generating a third machine-learning model based at least in part on the third frame and a label indicating that the first frame does not represent the predefined activity.

18. The one or more computer-readable storage media of claim 13, wherein the operations further comprise: deter-

mining a triggering event; and sending the second machine-learning model to the mobile cart in response to determining the triggering event.

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