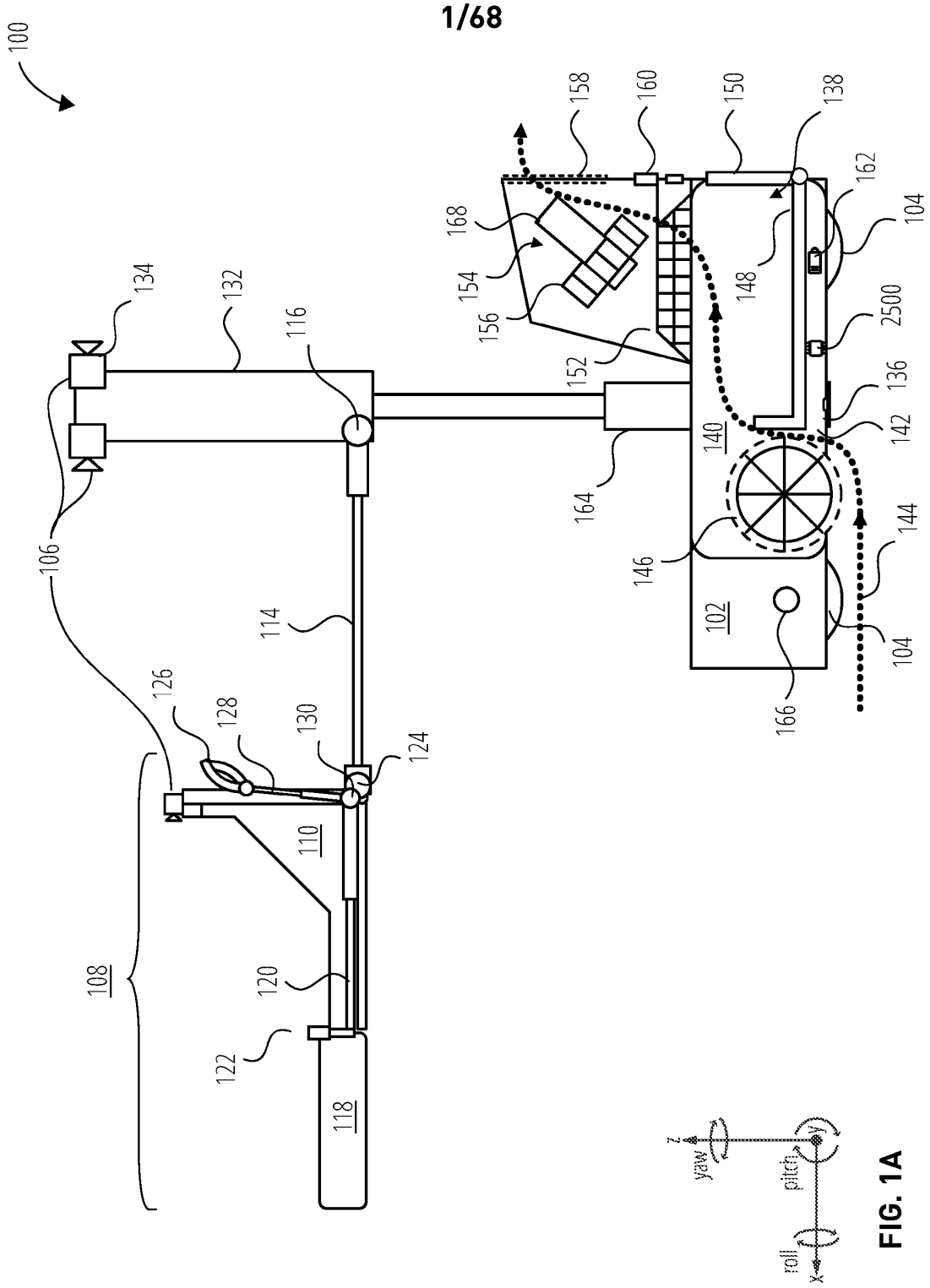

100
158
160
150
138
162
104
168
154
156
152
148
2500
136
142
140
164
146
144
102
104
166
134
132
116
106
114
126
128
130
124
110
108
120
122
118
z
yaw
pitch
y
roll
x

FIG. 1A

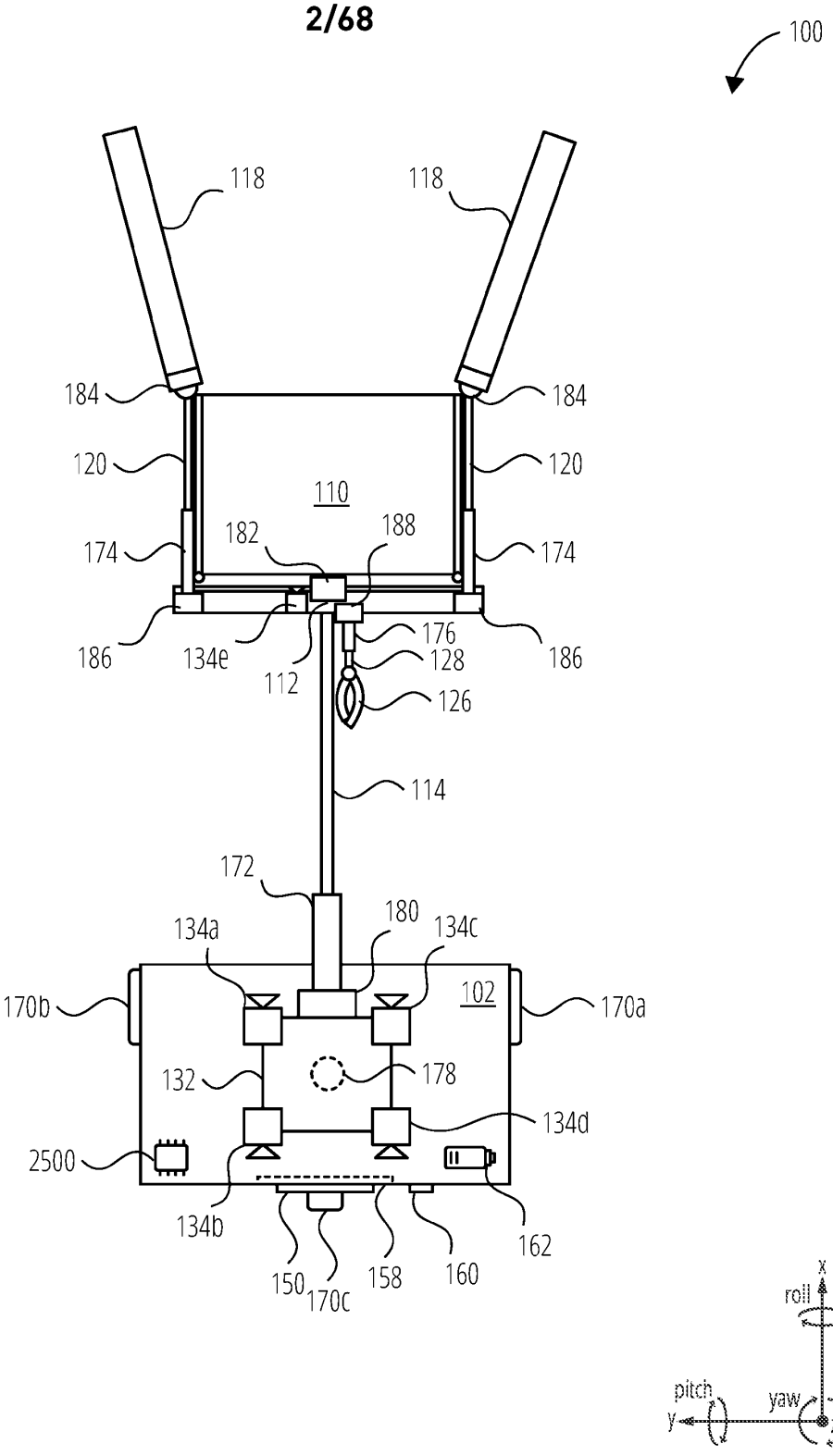

100
118
118
184
184
120
120
110
182
188
174
174
186
134e
112
176
128
126
186
114
172
180
134a
134c
102
170b
170a
132
178
134d
2500
134b
150
170c
158
160
162
x
roll
pitch
yaw
y
z

FIG. 1B

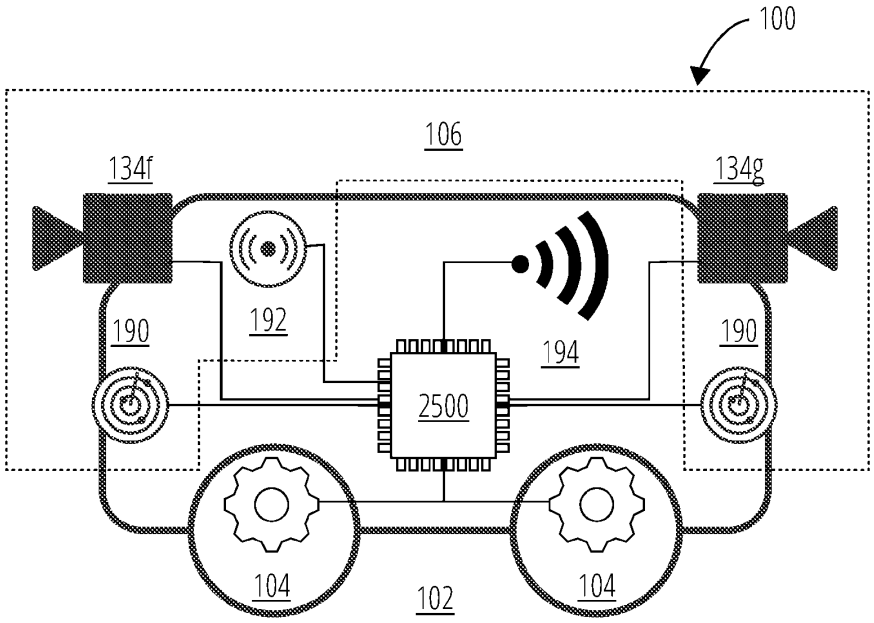

100
106
134f
134g
192
194
190
190
2500
104
104
102

FIG. 1C

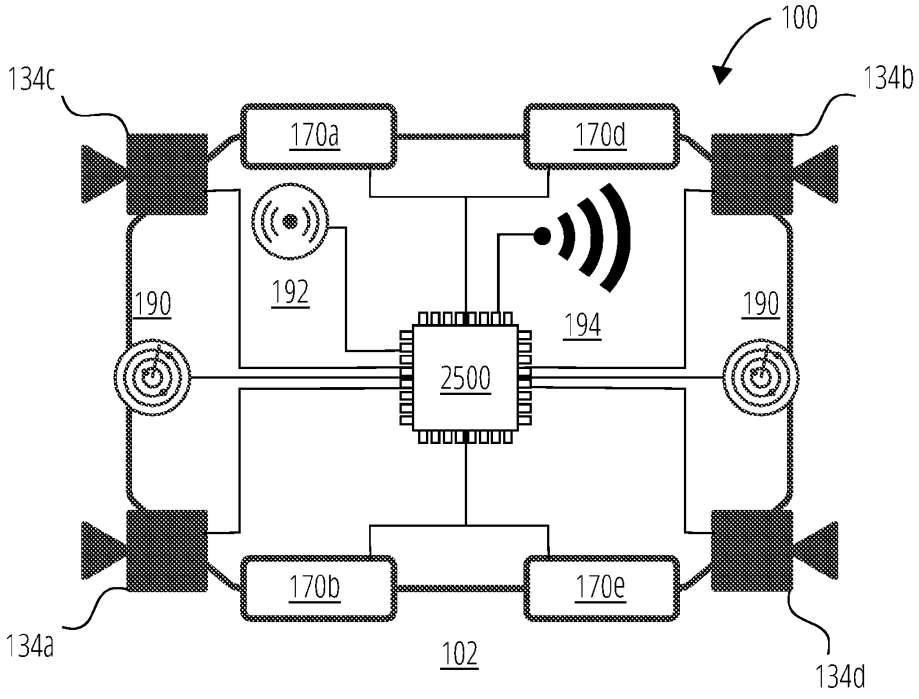

100
134c
134b
170a
170d
192
194
190
190
2500
170b
170e
134a
102
134d

FIG. 1D

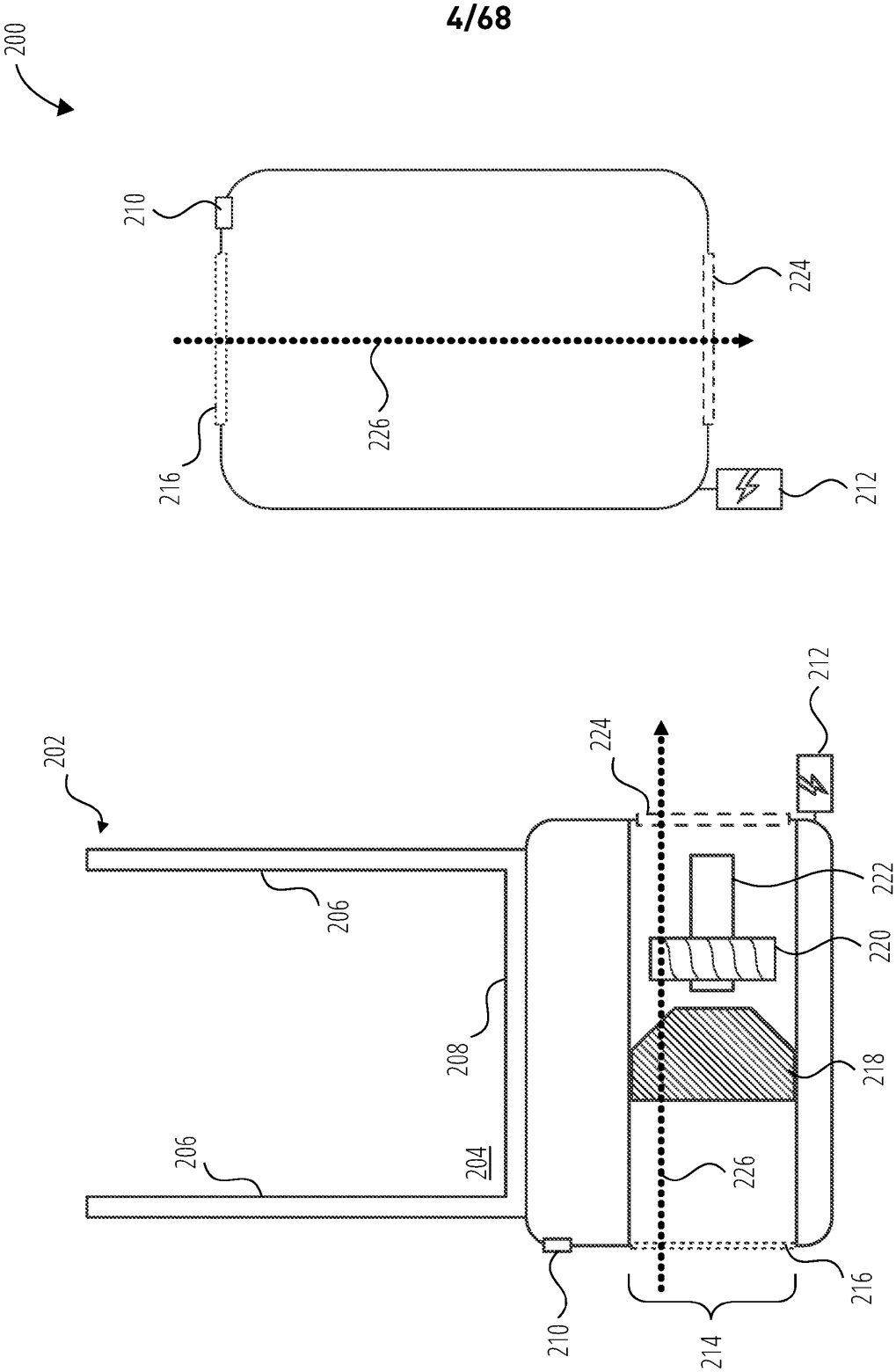

200
210
224
226
216
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202
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208
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206
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224
222
220
218
226
216
210
214

FIG. 2B

FIG. 2A

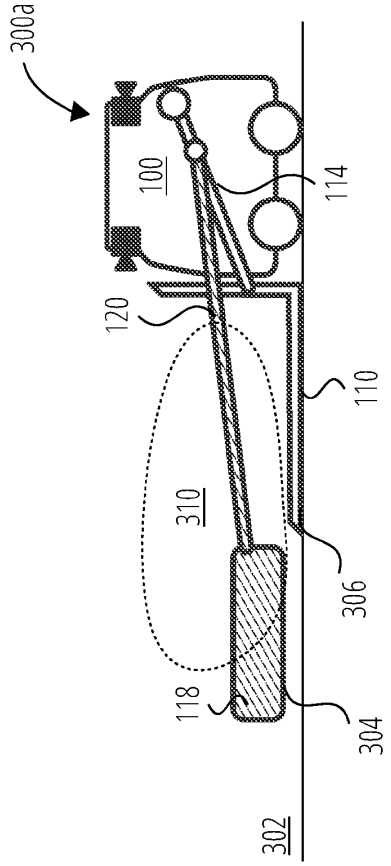


FIG. 3A

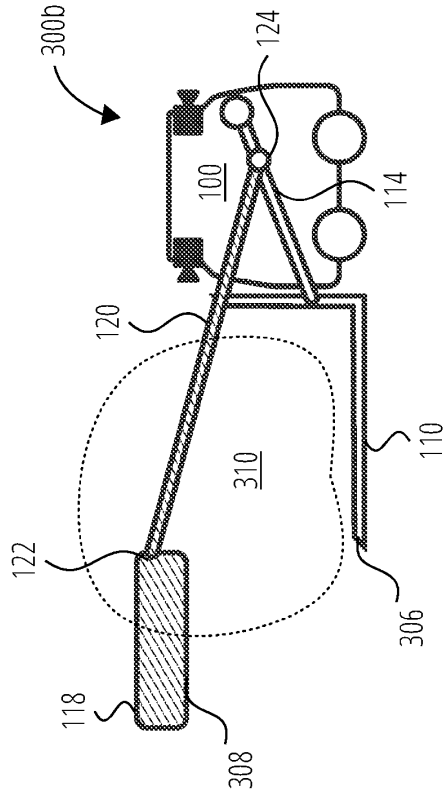


FIG. 3B

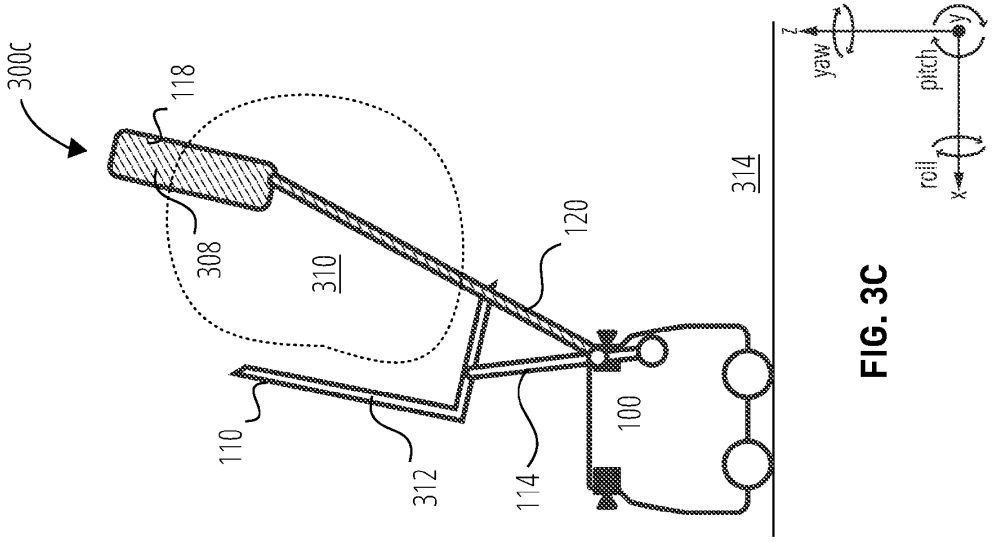


FIG. 3C

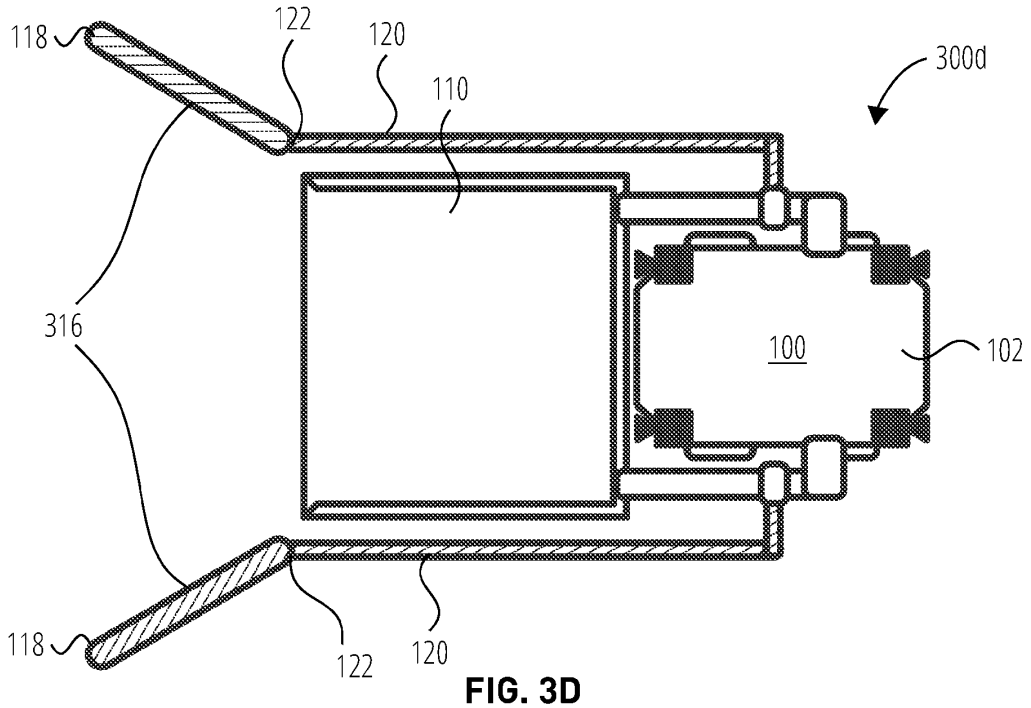

118
122
120
110
300d
316
100
102
118
122
120

FIG. 3D

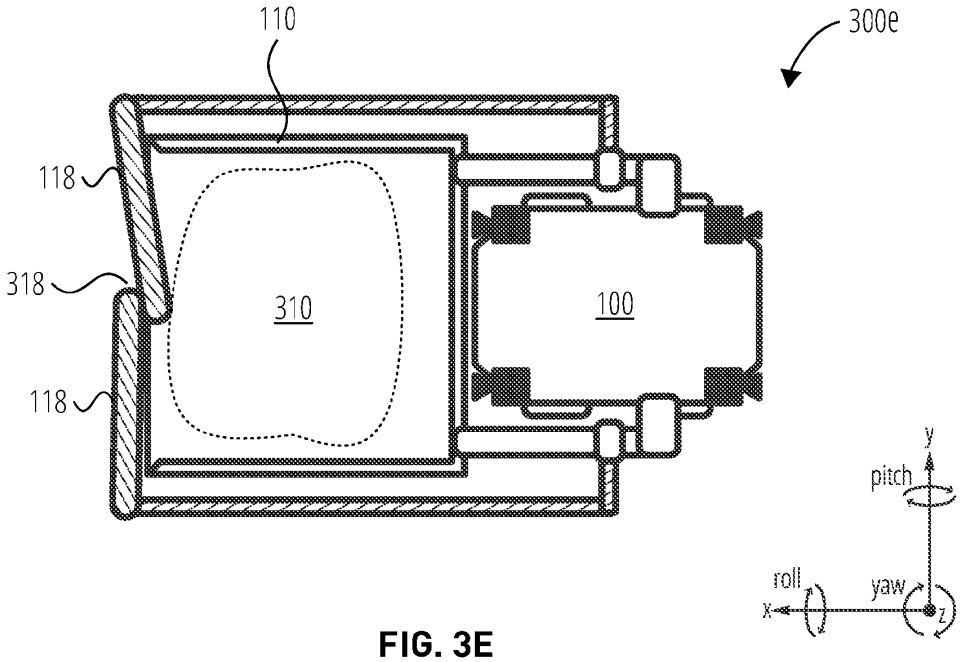

110
300e
118
318
310
100
118
y
pitch
roll
yaw
x
z

FIG. 3E

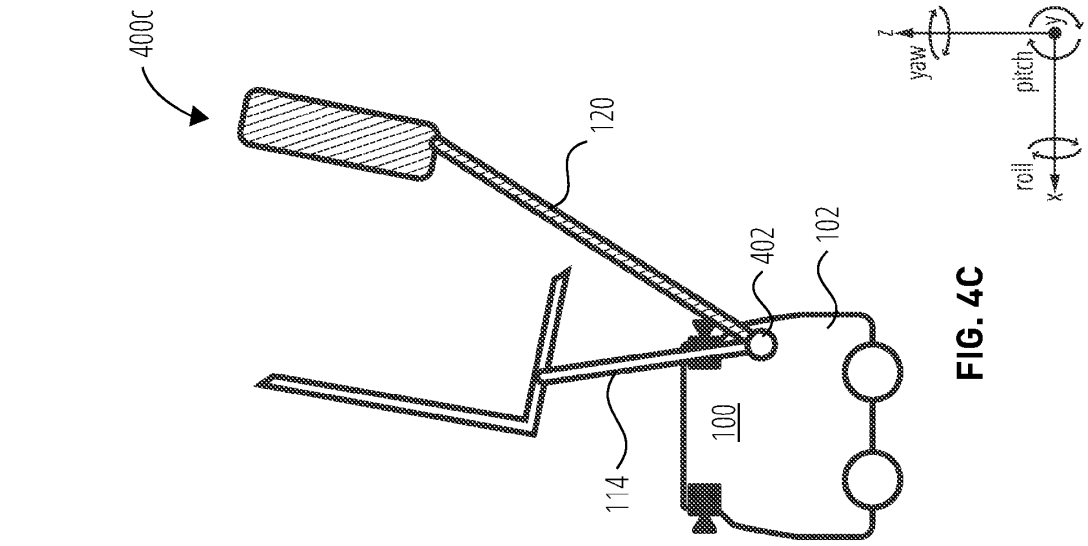


FIG. 4C

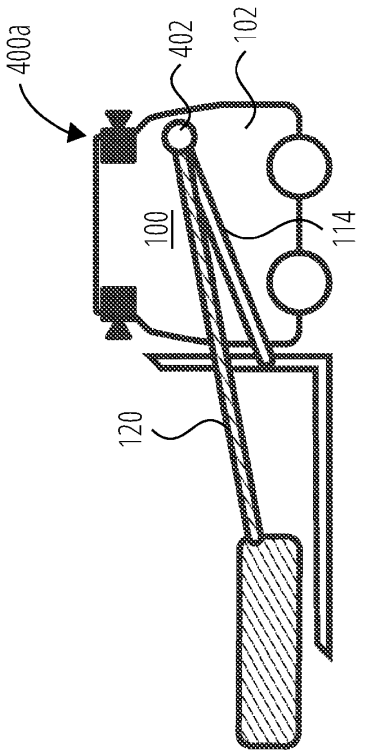


FIG. 4A

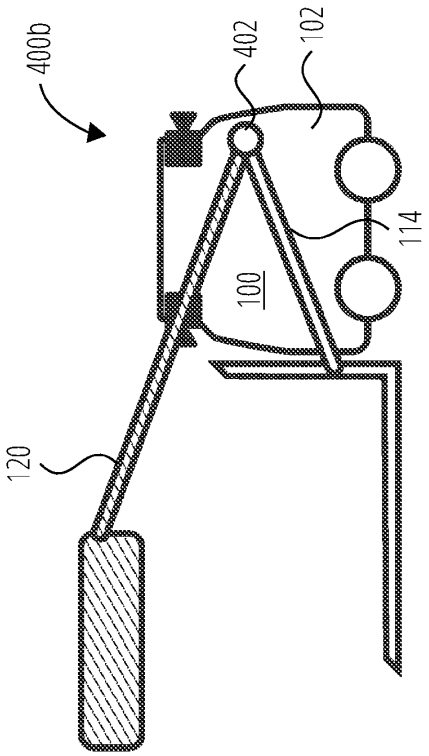


FIG. 4B

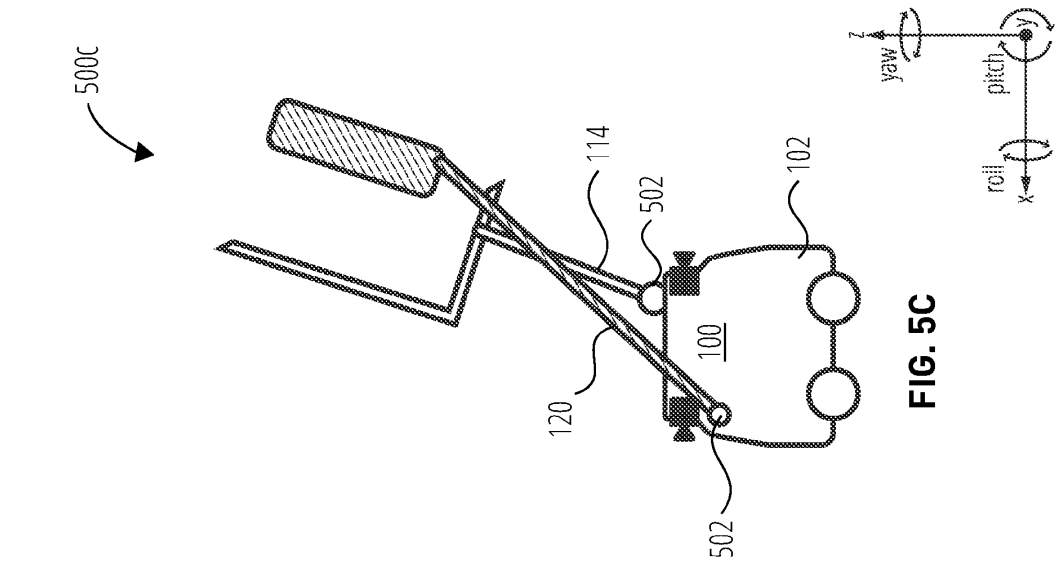


FIG. 5C

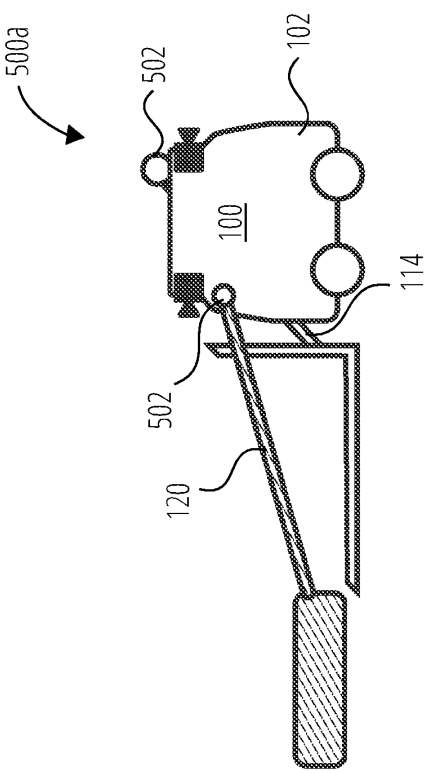


FIG. 5A

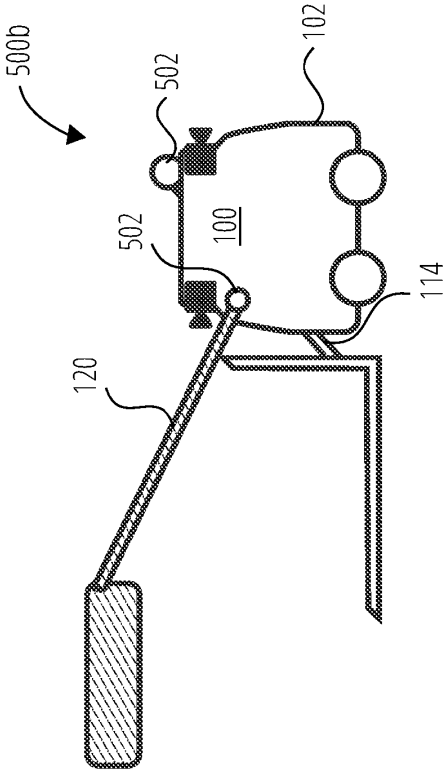


FIG. 5B

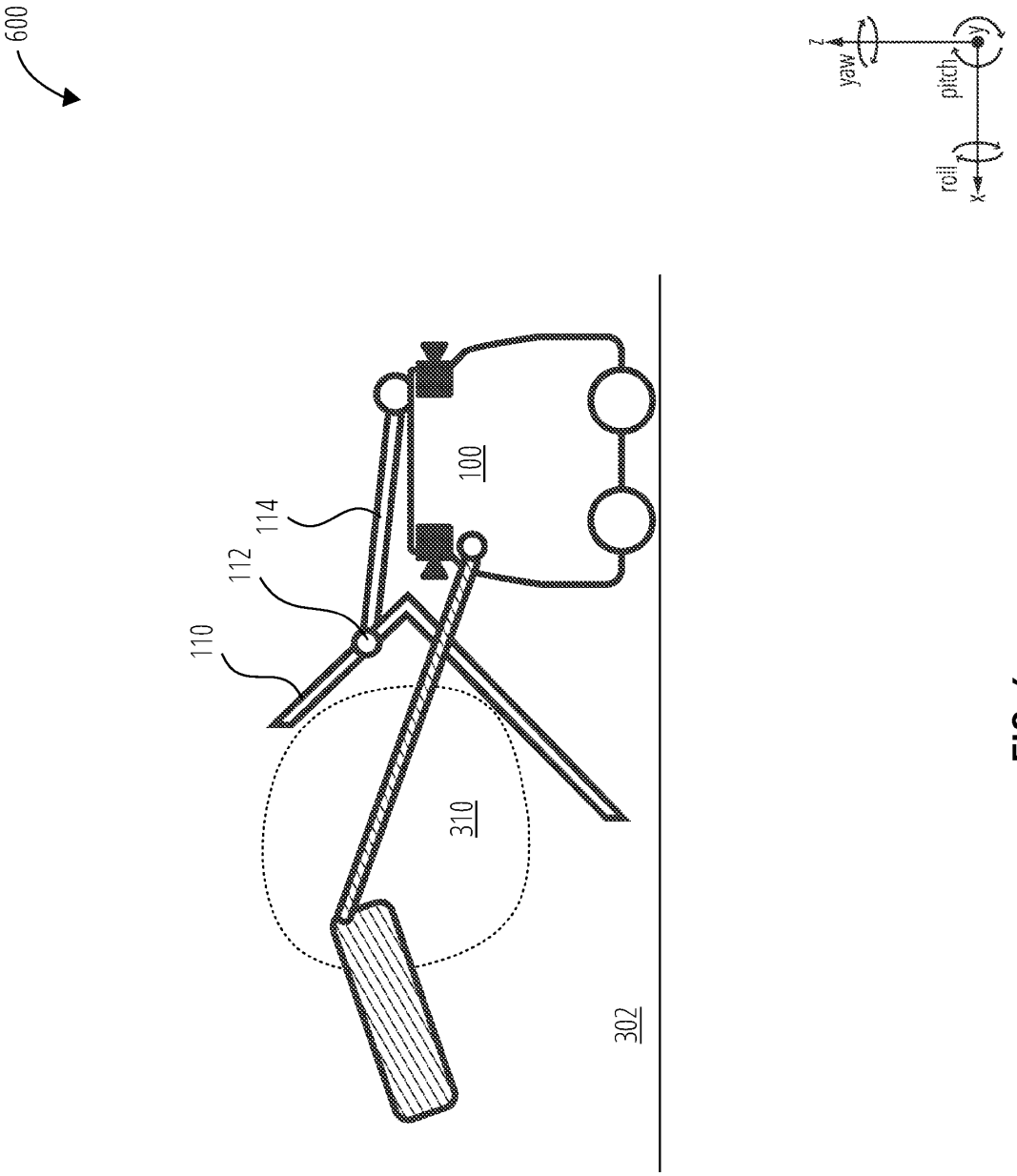


FIG. 6

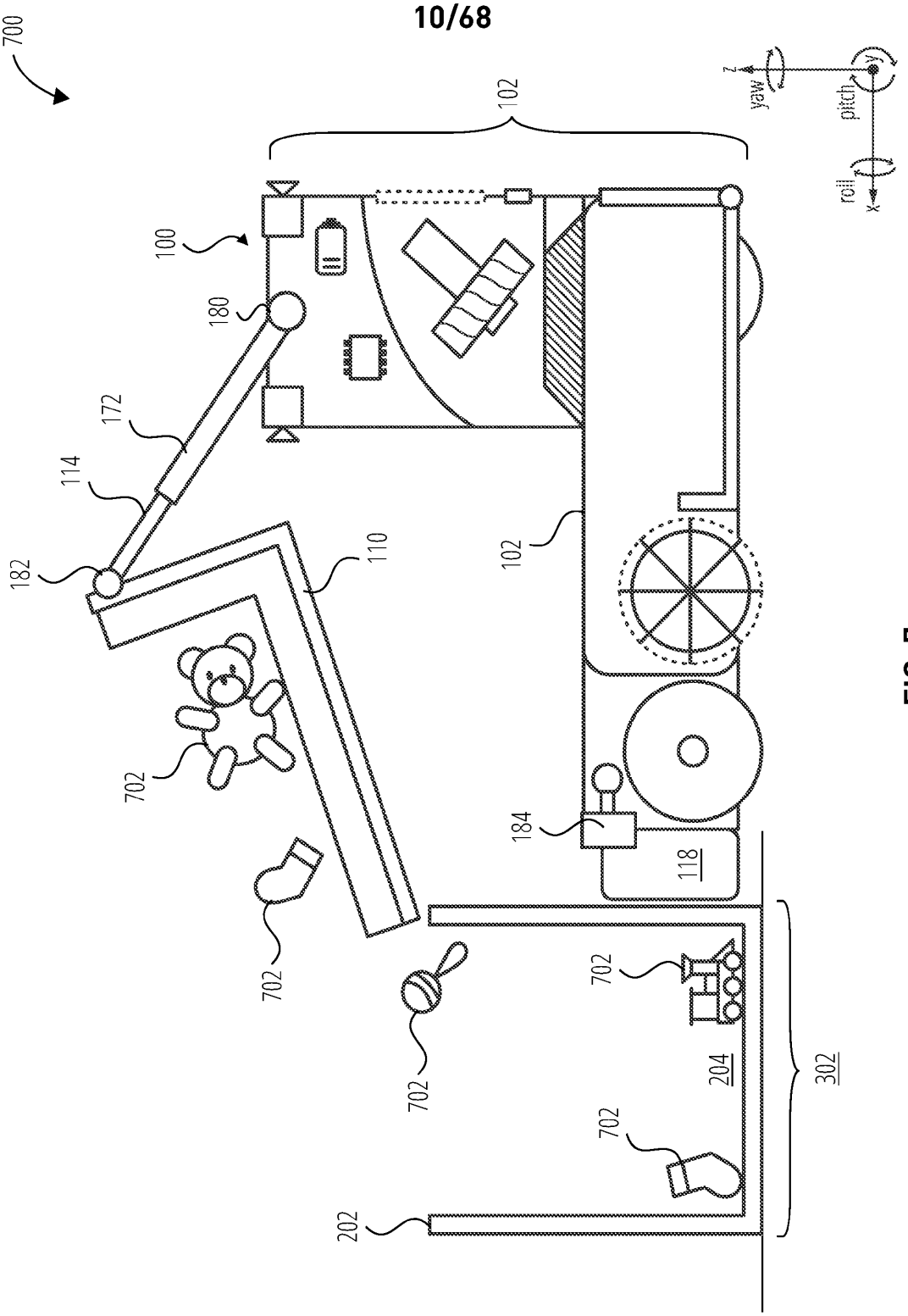

700
102
z
yaw
y
pitch
roll
x
100
180
172
114
182
110
102
702
184
118
702
702
204
302
702
202

FIG. 7

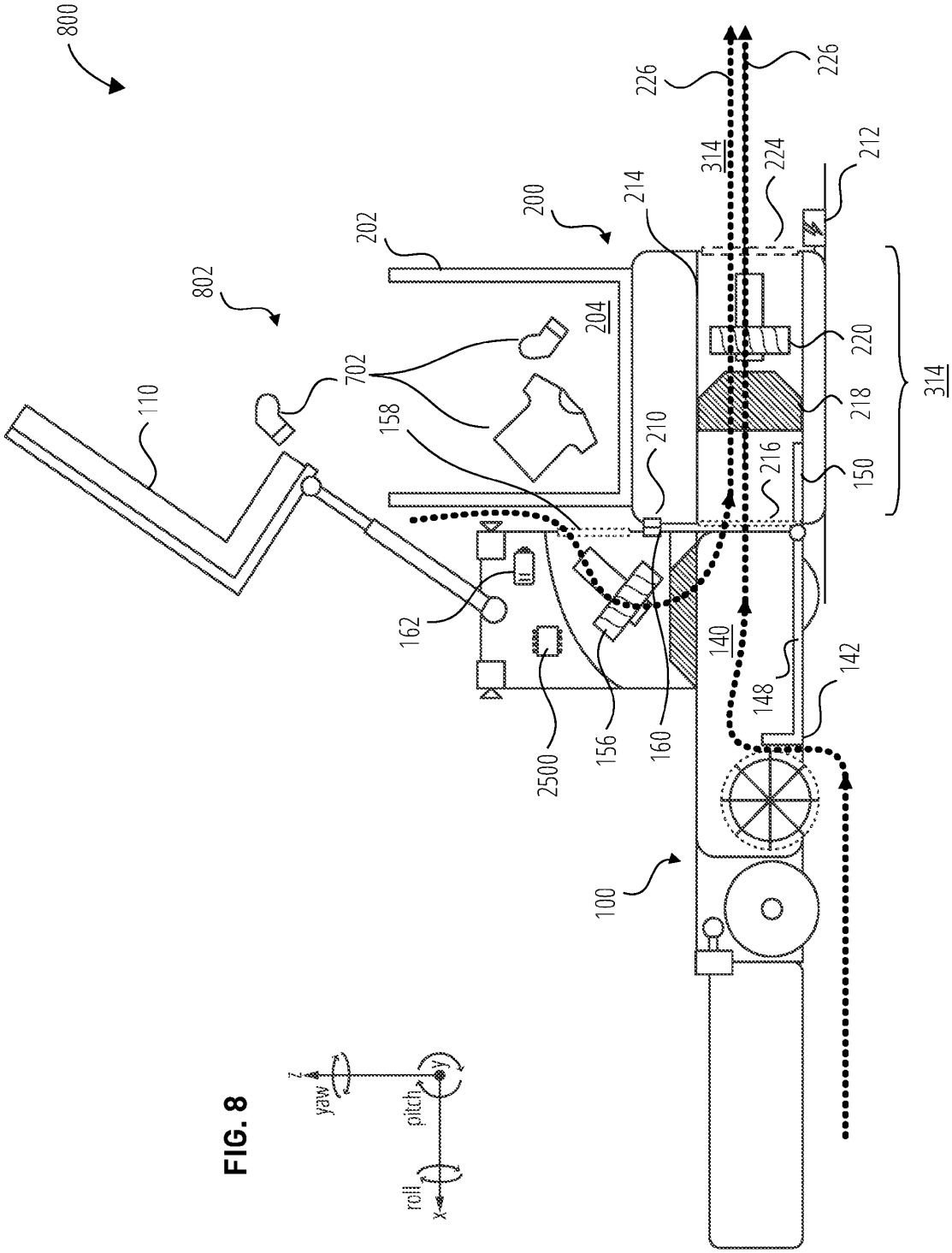

800
802
110
702
158
202
200
204
214
210
226
226
314
224
212
220
218
216
150
314
162
140
142
148
2500
156
160
100
z
yaw
pitch
y
roll
x

FIG. 8

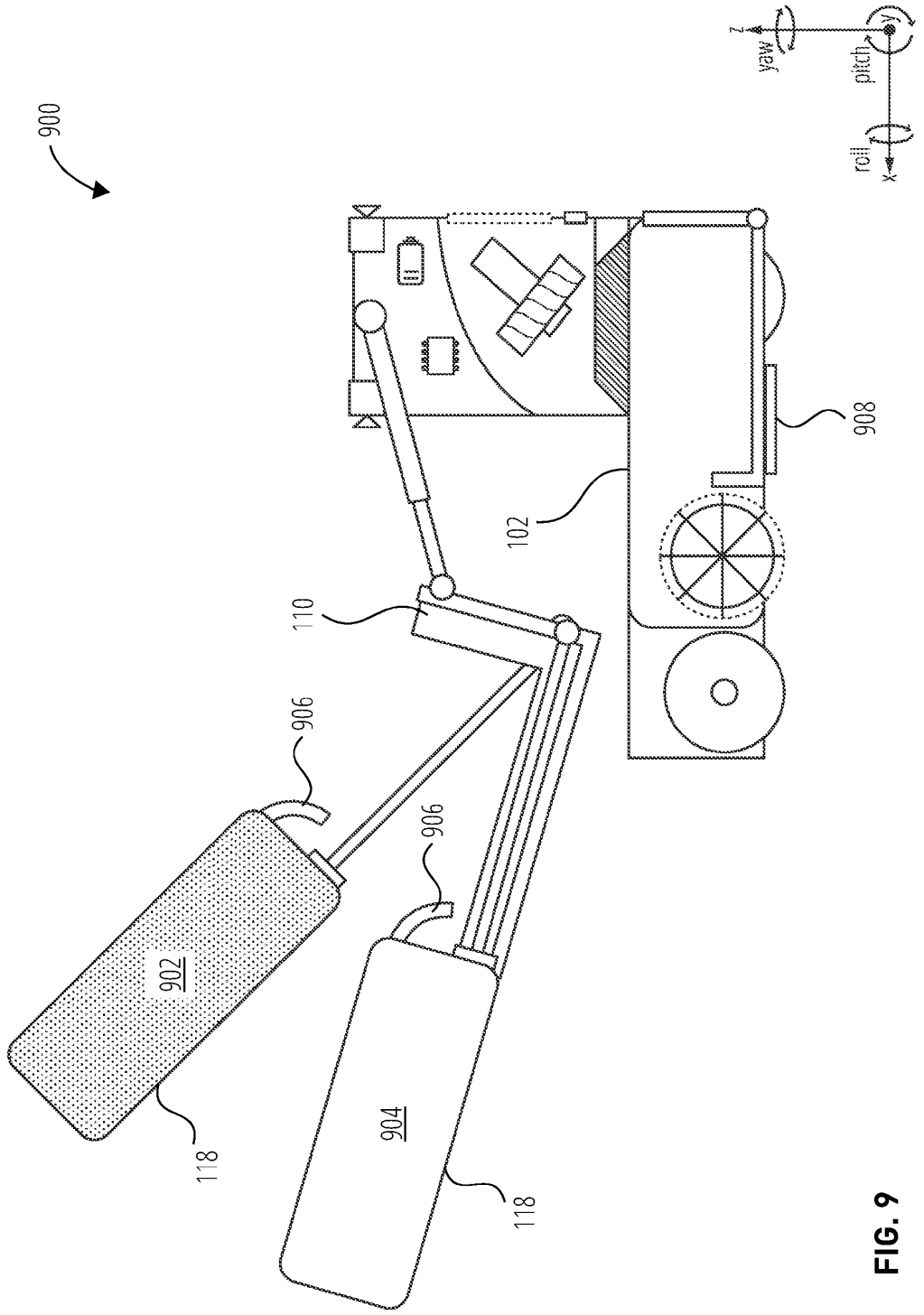


FIG. 9

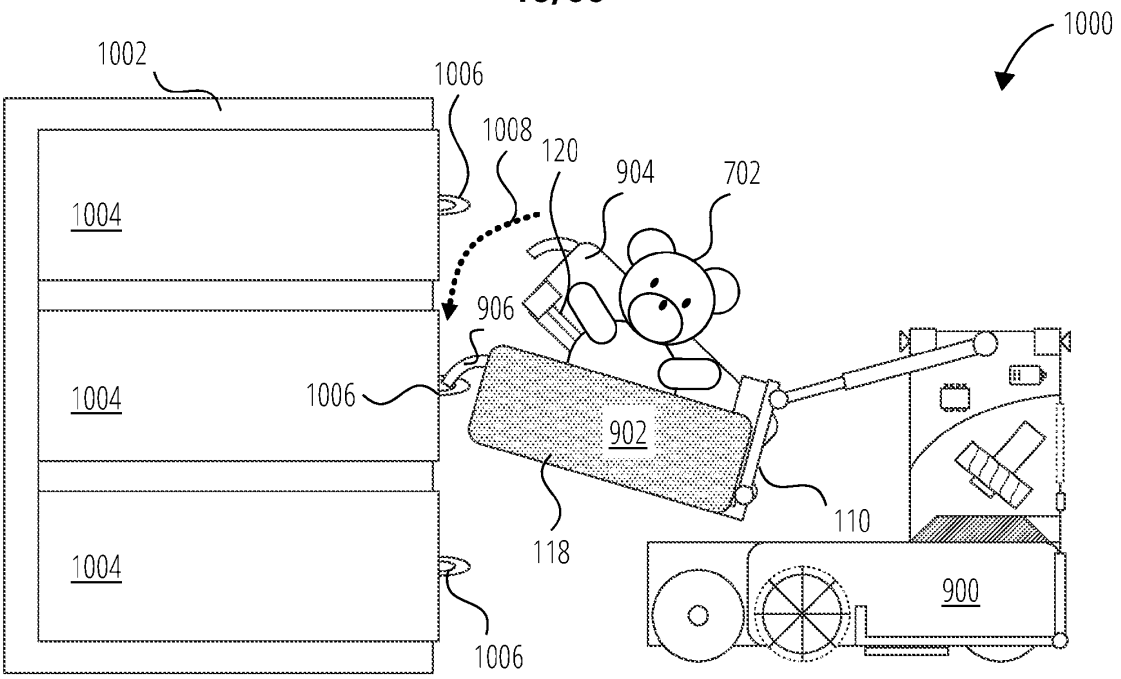


FIG. 10A

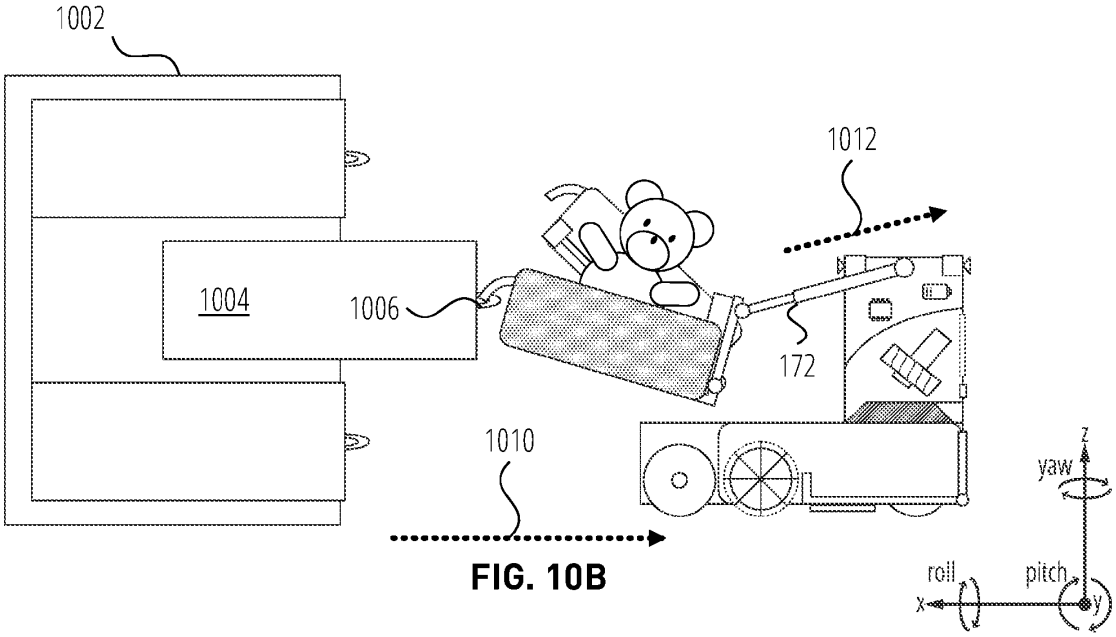


FIG. 10B

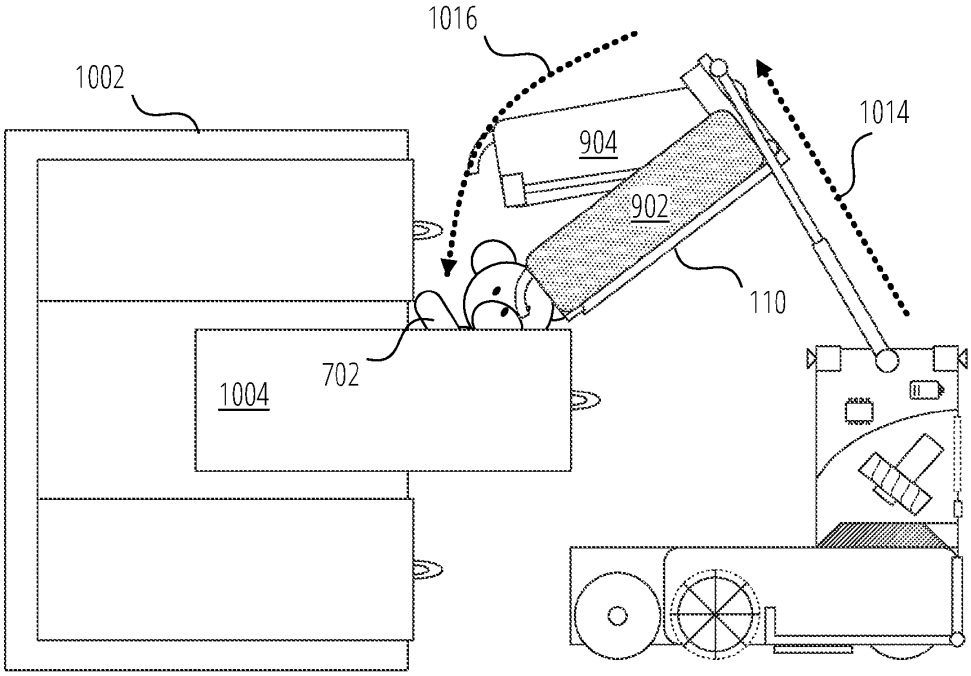


FIG. 10C

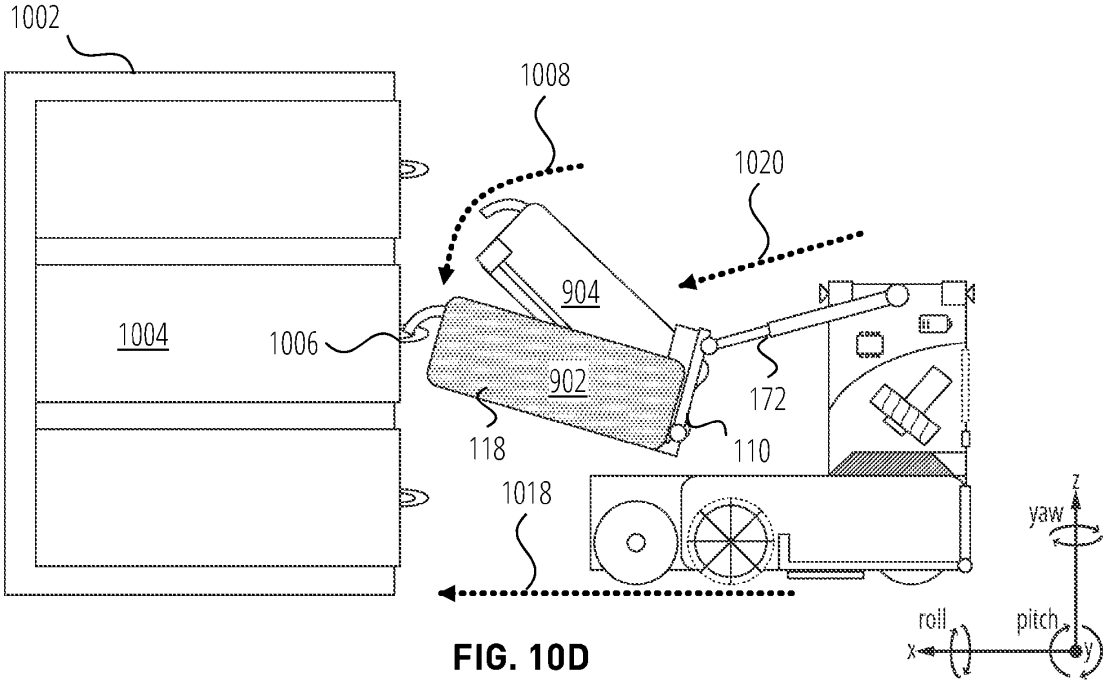


FIG. 10D

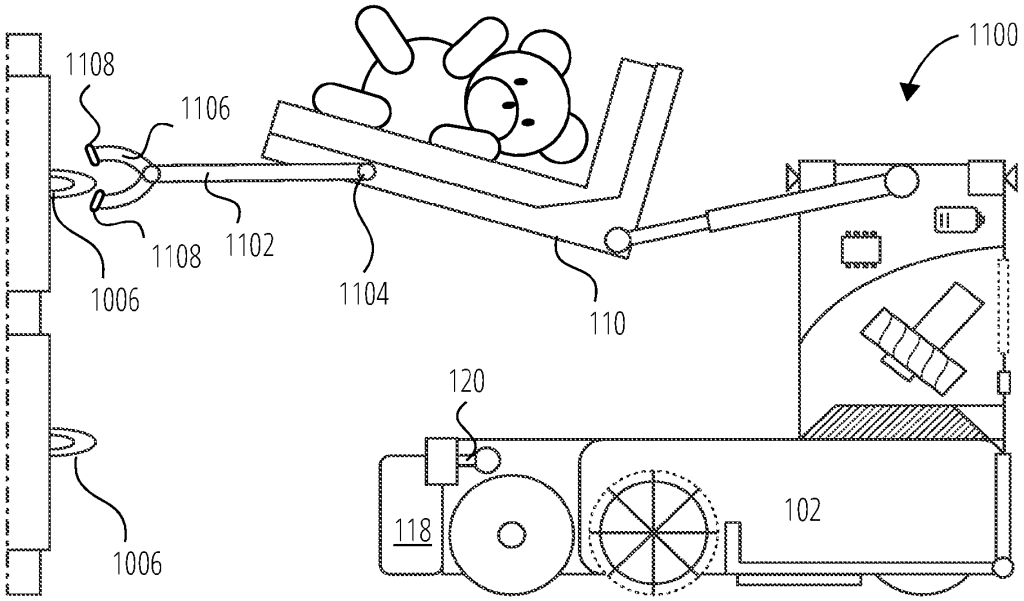

1100
1108
1106
1108
1102
1006
1104
110
120
102
118
1006

FIG. 11

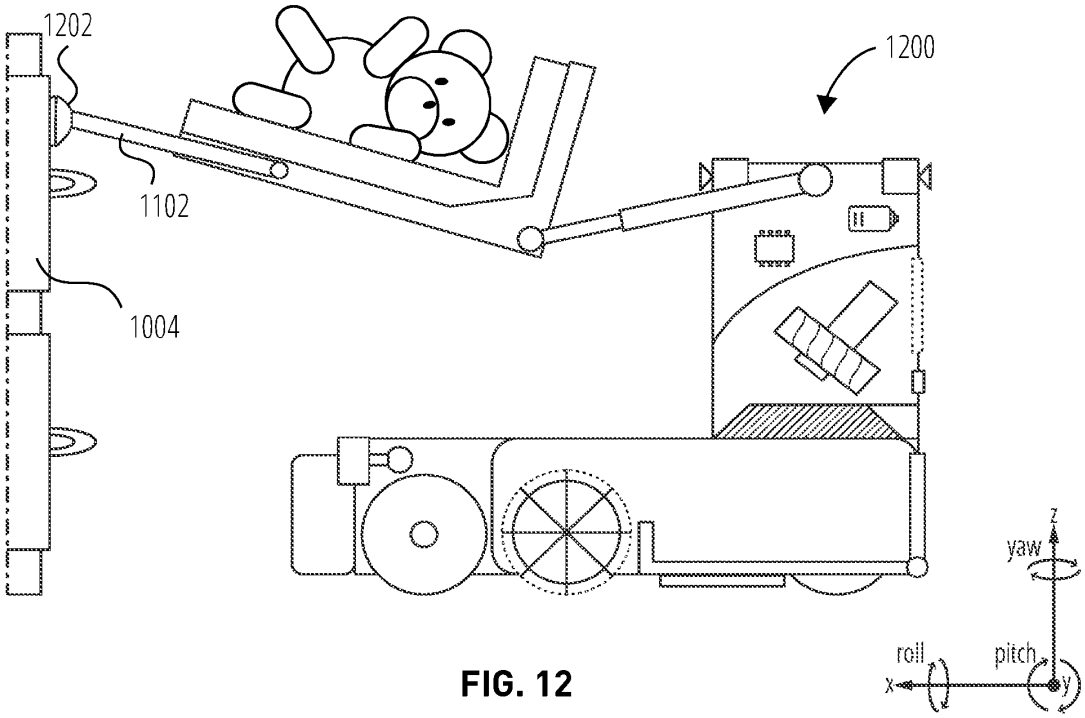

1202
1200
1102
1004
z
yaw
roll
pitch
x
y

FIG. 12

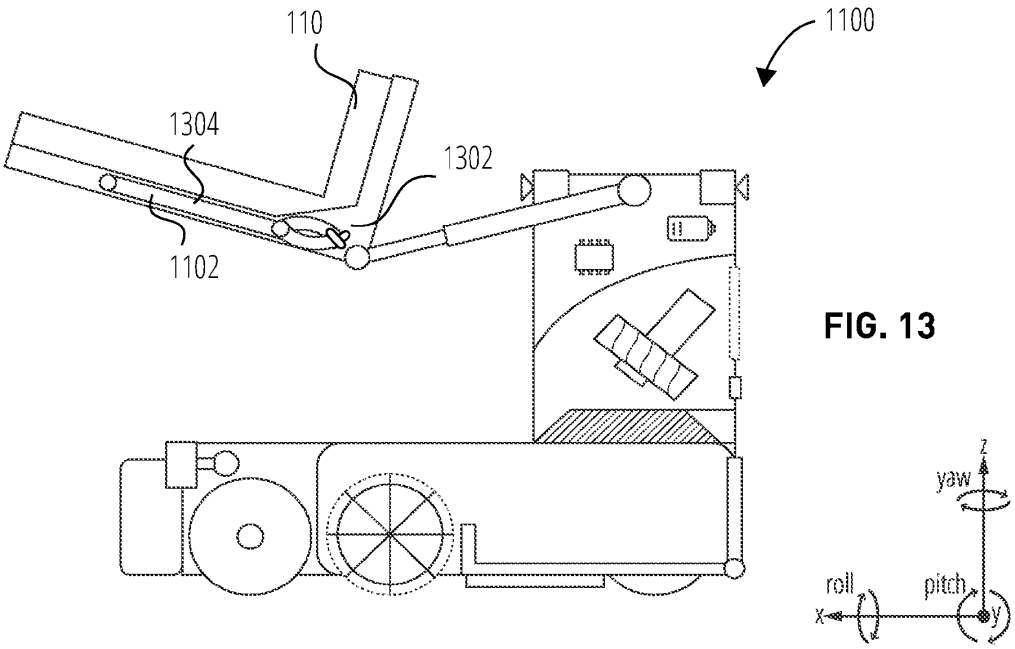

110
1100
1304
1302
1102
z
yaw
roll
pitch
x
y

FIG. 13

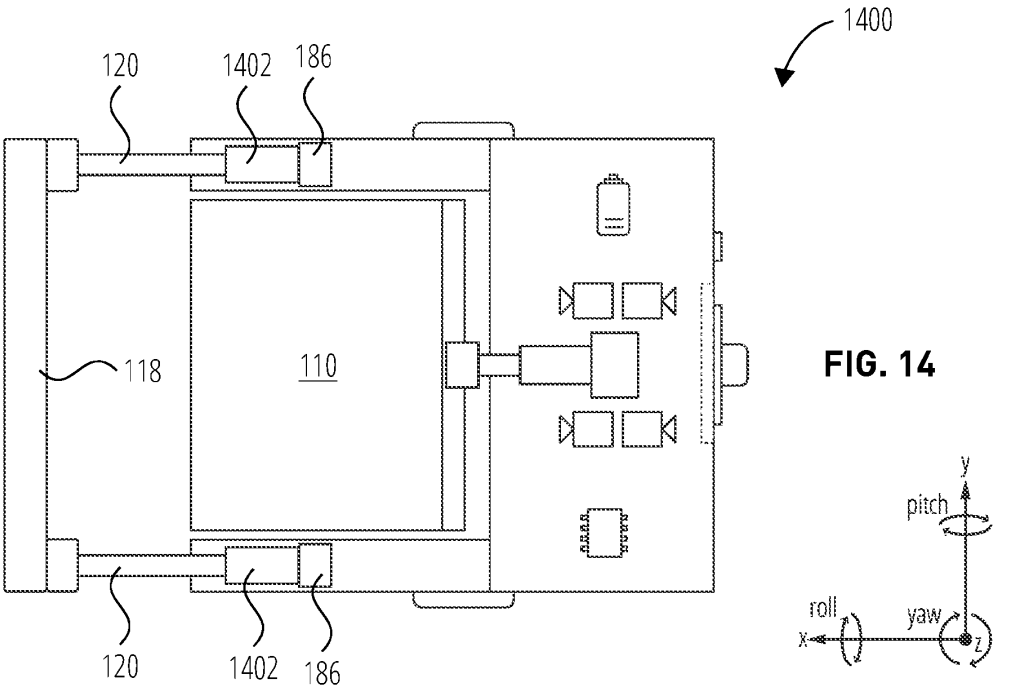

1400
120
1402
186
118
110
120
1402
186
y
pitch
roll
yaw
x
z

FIG. 14

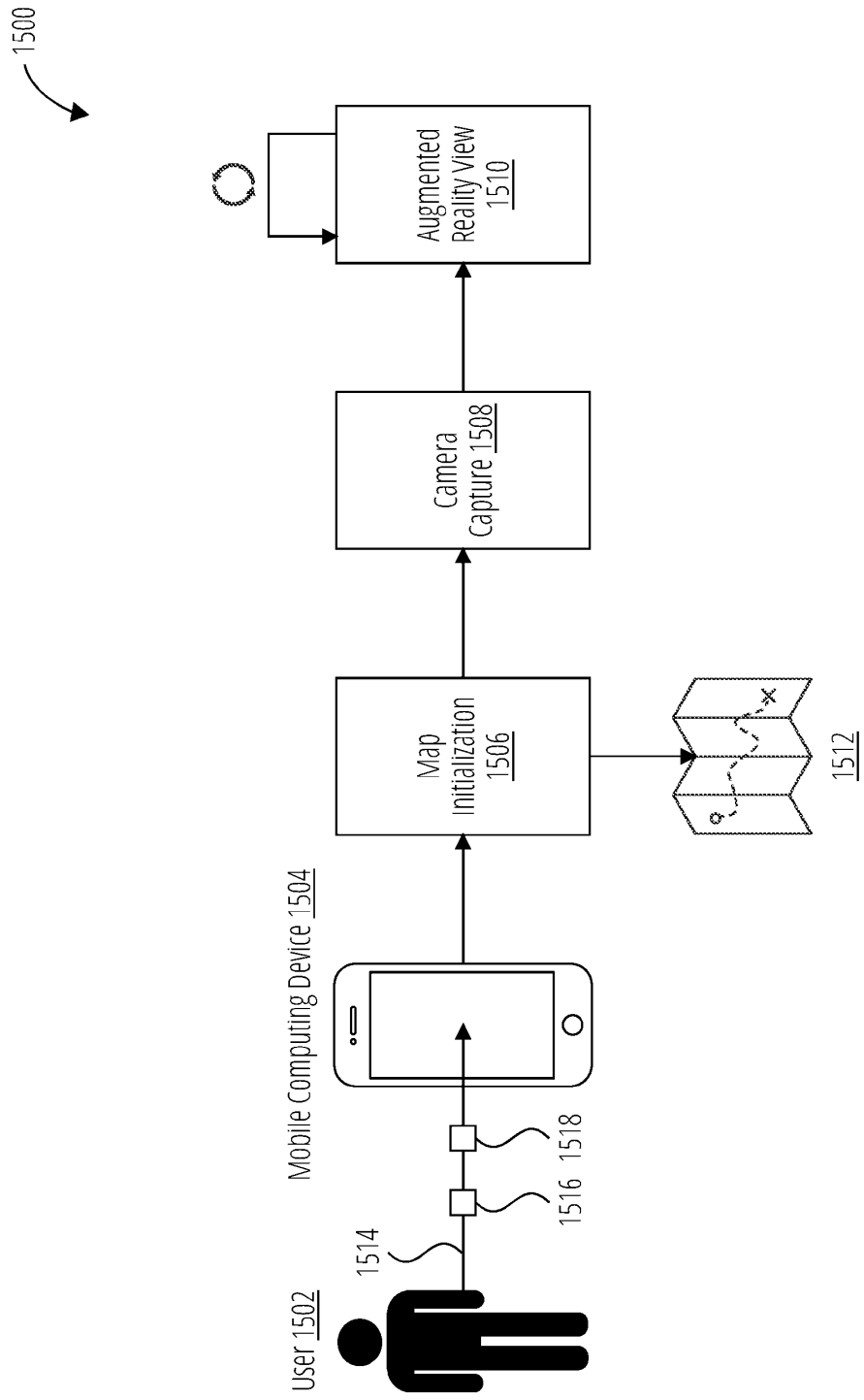

1500
Augmented Reality View 1510
Camera Capture 1508
Map Initialization 1506
1512
Mobile Computing Device 1504
User 1502
1514
1516
1518

FIG. 15

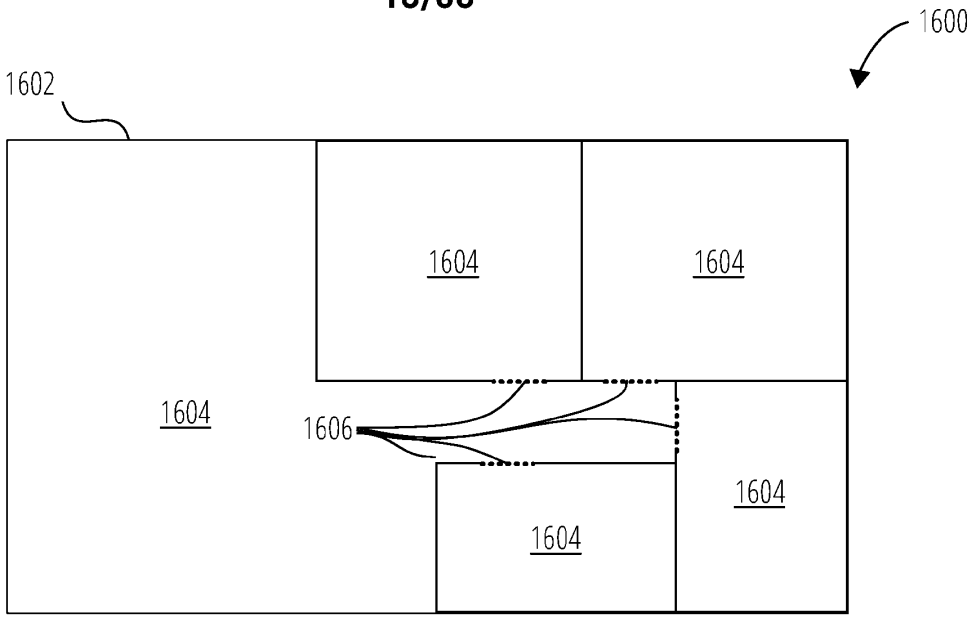


FIG. 16A

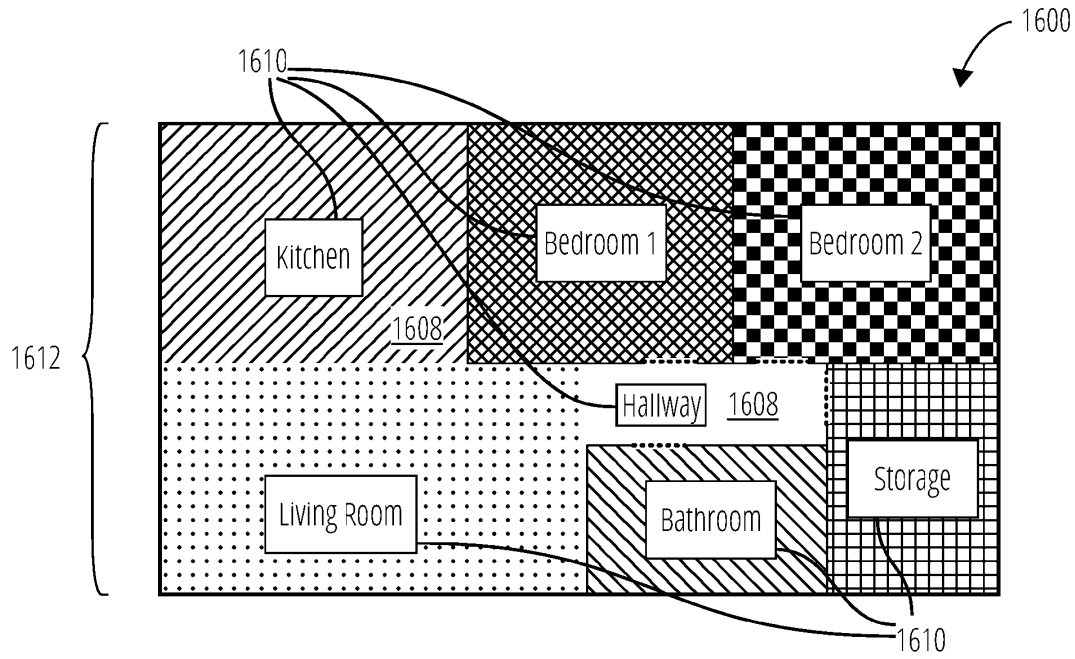


FIG. 16B

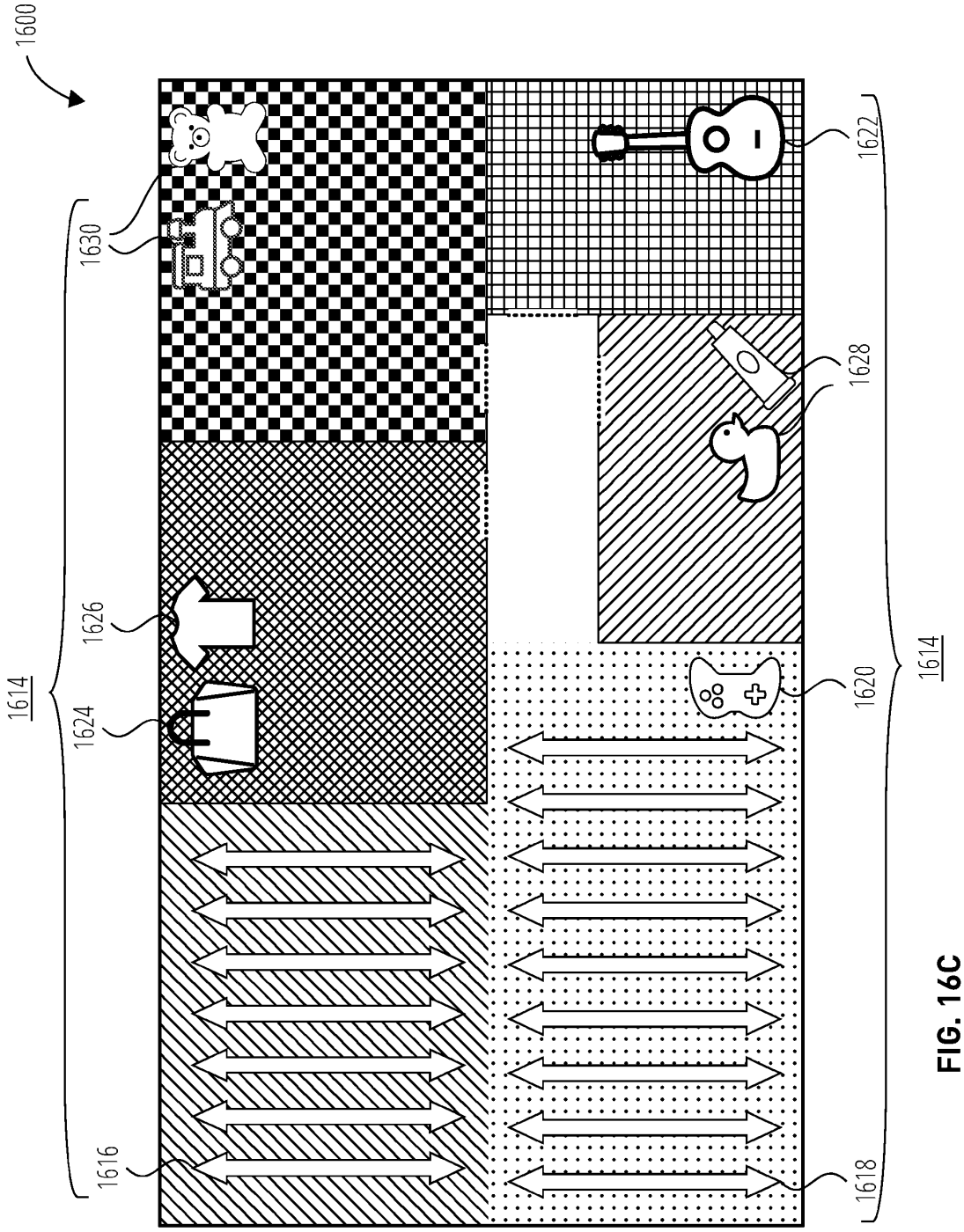


FIG. 16C

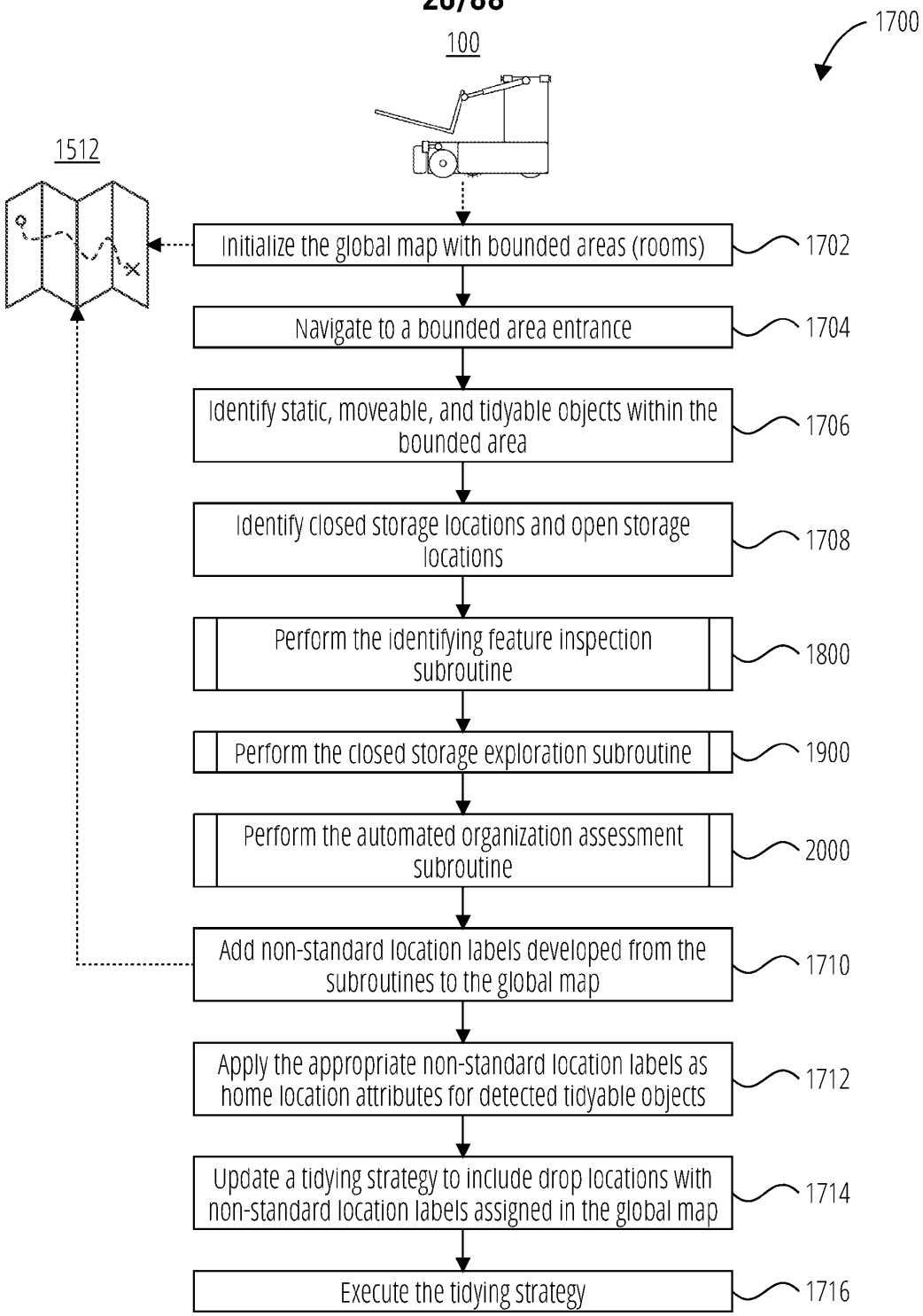

1700
100
1512
Initialize the global map with bounded areas (rooms)
1702
Navigate to a bounded area entrance
1704
Identify static, moveable, and tidyable objects within the bounded area
1706
Identify closed storage locations and open storage locations
1708
Perform the identifying feature inspection subroutine
1800
Perform the closed storage exploration subroutine
1900
Perform the automated organization assessment subroutine
2000
Add non-standard location labels developed from the subroutines to the global map
1710
Apply the appropriate non-standard location labels as home location attributes for detected tidyable objects
1712
Update a tidying strategy to include drop locations with non-standard location labels assigned in the global map
1714
Execute the tidying strategy
1716

FIG. 17

FIG. 18

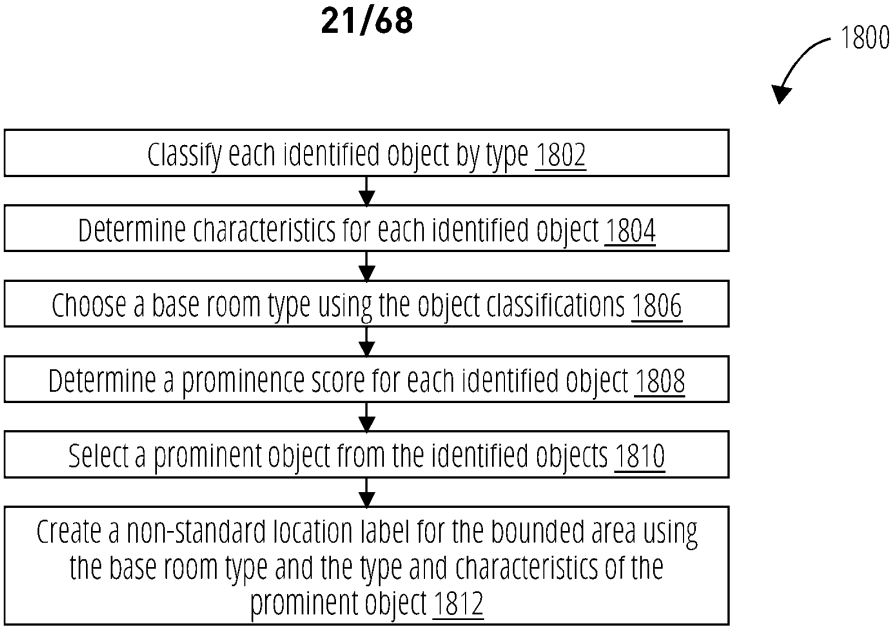
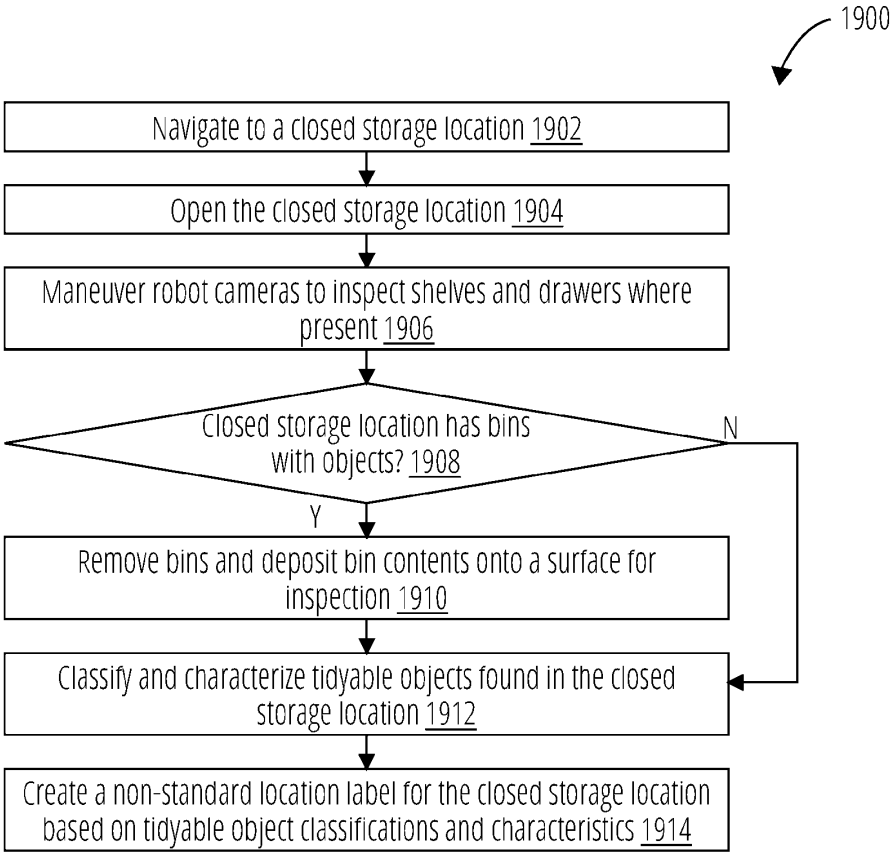

1800
Classify each identified object by type 1802
Determine characteristics for each identified object 1804
Choose a base room type using the object classifications 1806
Determine a prominence score for each identified object 1808
Select a prominent object from the identified objects 1810
Create a non-standard location label for the bounded area using the base room type and the type and characteristics of the prominent object 1812

FIG. 19


1900
Navigate to a closed storage location 1902
Open the closed storage location 1904
Maneuver robot cameras to inspect shelves and drawers where present 1906
Closed storage location has bins with objects? 1908
N
Y
Remove bins and deposit bin contents onto a surface for inspection 1910
Classify and characterize tidyable objects found in the closed storage location 1912
Create a non-standard location label for the closed storage location based on tidyable object classifications and characteristics 1914

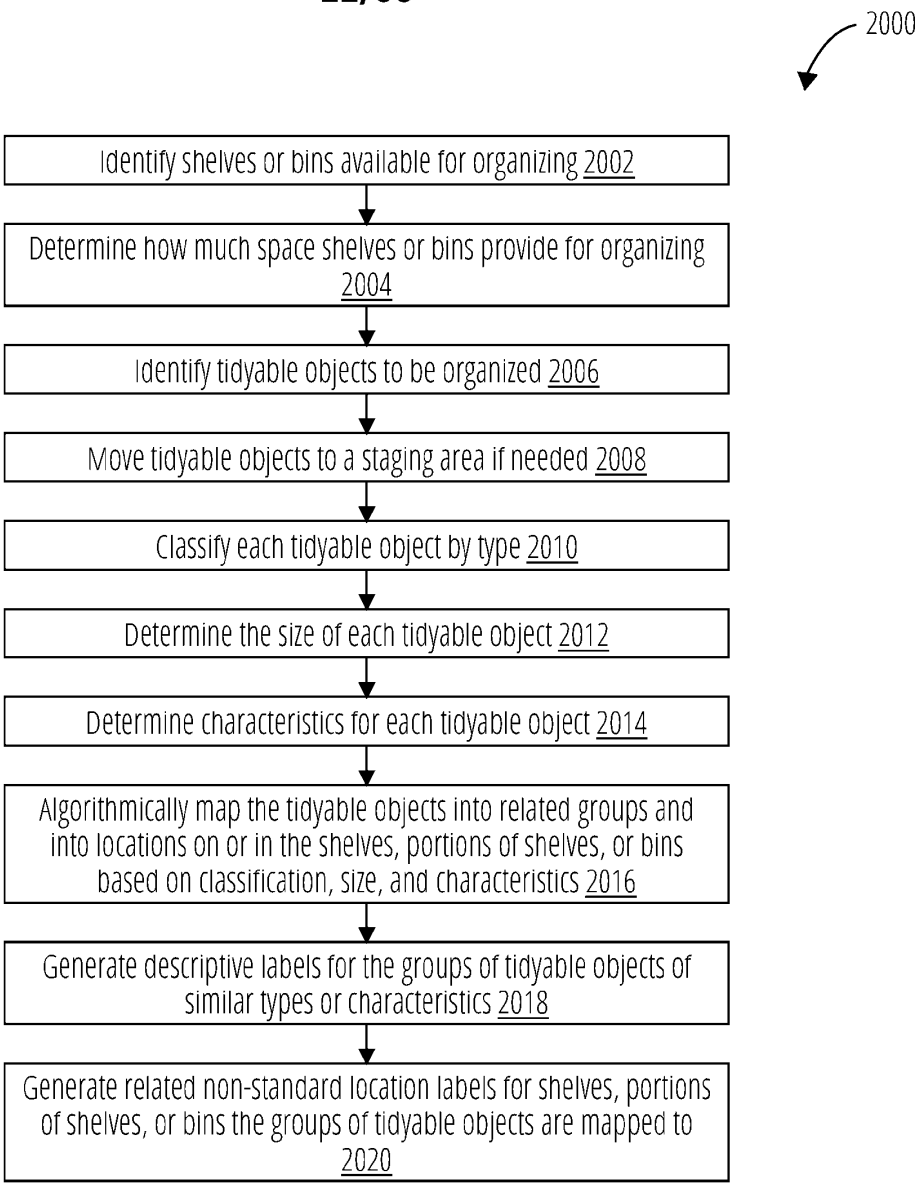

2000
Identify shelves or bins available for organizing 2002
Determine how much space shelves or bins provide for organizing 2004
Identify tidyable objects to be organized 2006
Move tidyable objects to a staging area if needed 2008
Classify each tidyable object by type 2010
Determine the size of each tidyable object 2012
Determine characteristics for each tidyable object 2014
Algorithmically map the tidyable objects into related groups and into locations on or in the shelves, portions of shelves, or bins based on classification, size, and characteristics 2016
Generate descriptive labels for the groups of tidyable objects of similar types or characteristics 2018
Generate related non-standard location labels for shelves, portions of shelves, or bins the groups of tidyable objects are mapped to 2020

FIG. 20

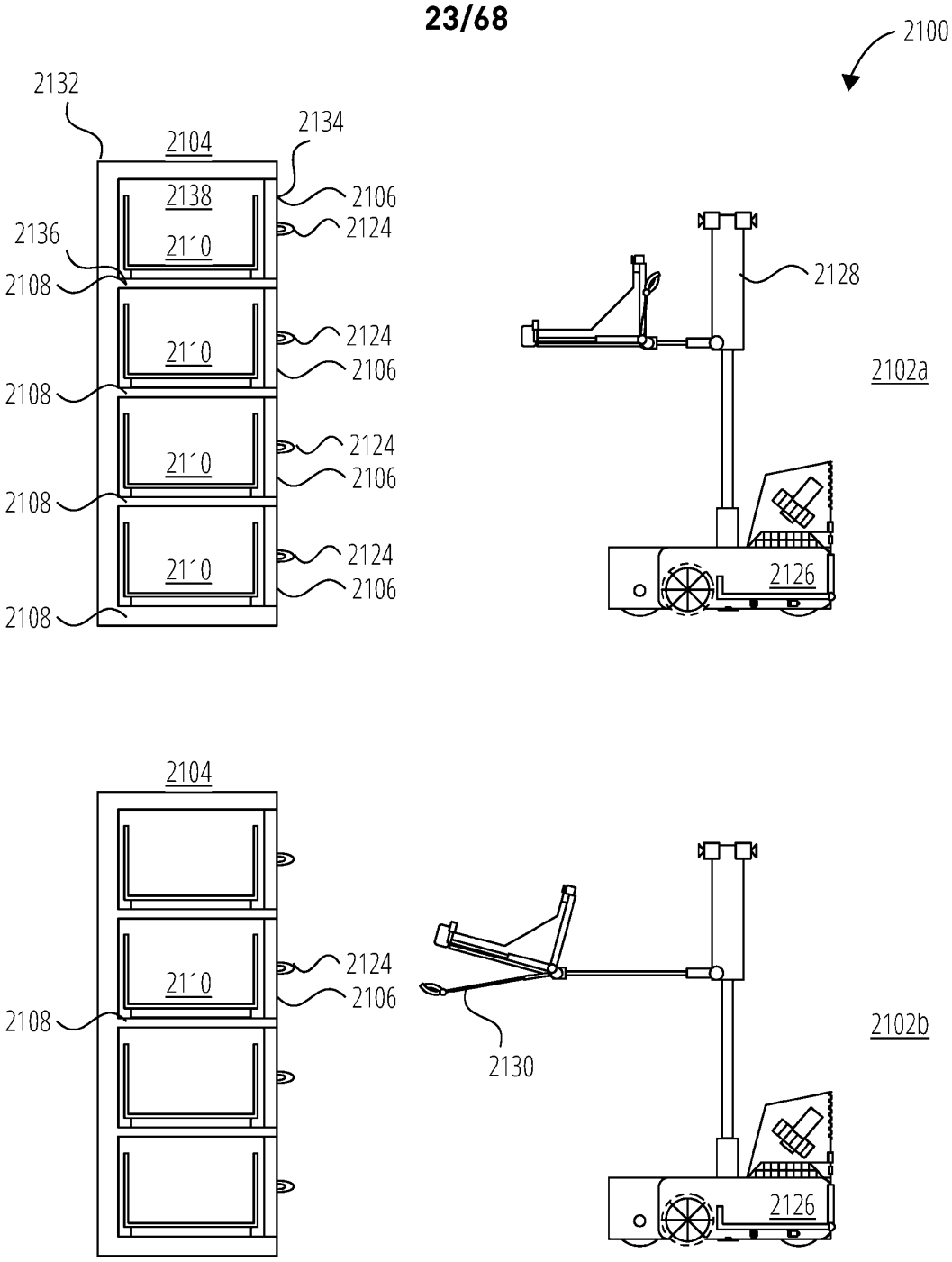

2100
2132
2104
2134
2138
2106
2124
2136
2110
2108
2128
2102a
2126
2104
2124
2106
2110
2108
2130
2102b
2126

FIG. 21A

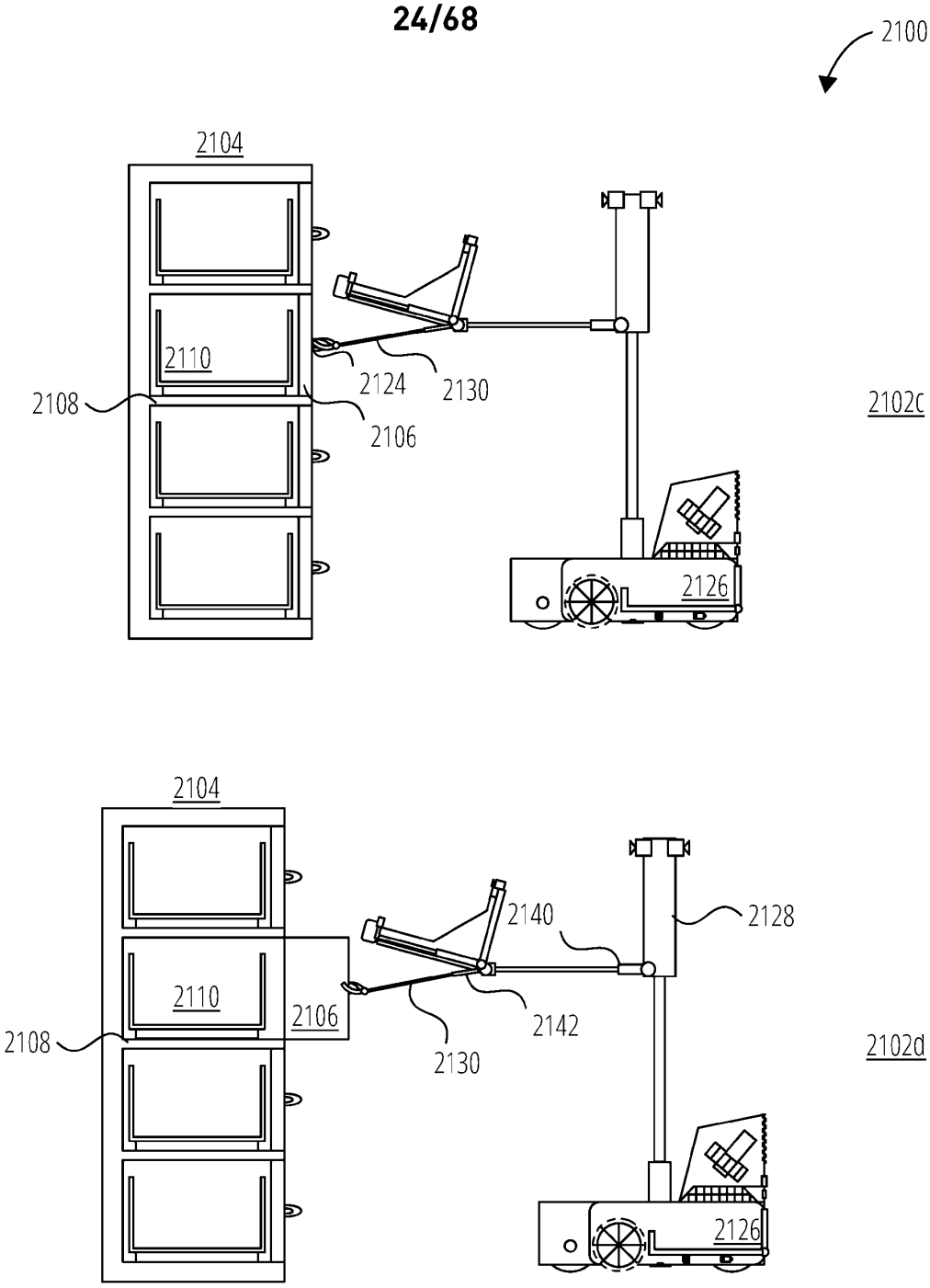

2100
2104
2110
2108
2124
2130
2106
2102c
2126
2104
2140
2128
2110
2106
2108
2142
2130
2102d
2126

FIG. 21B

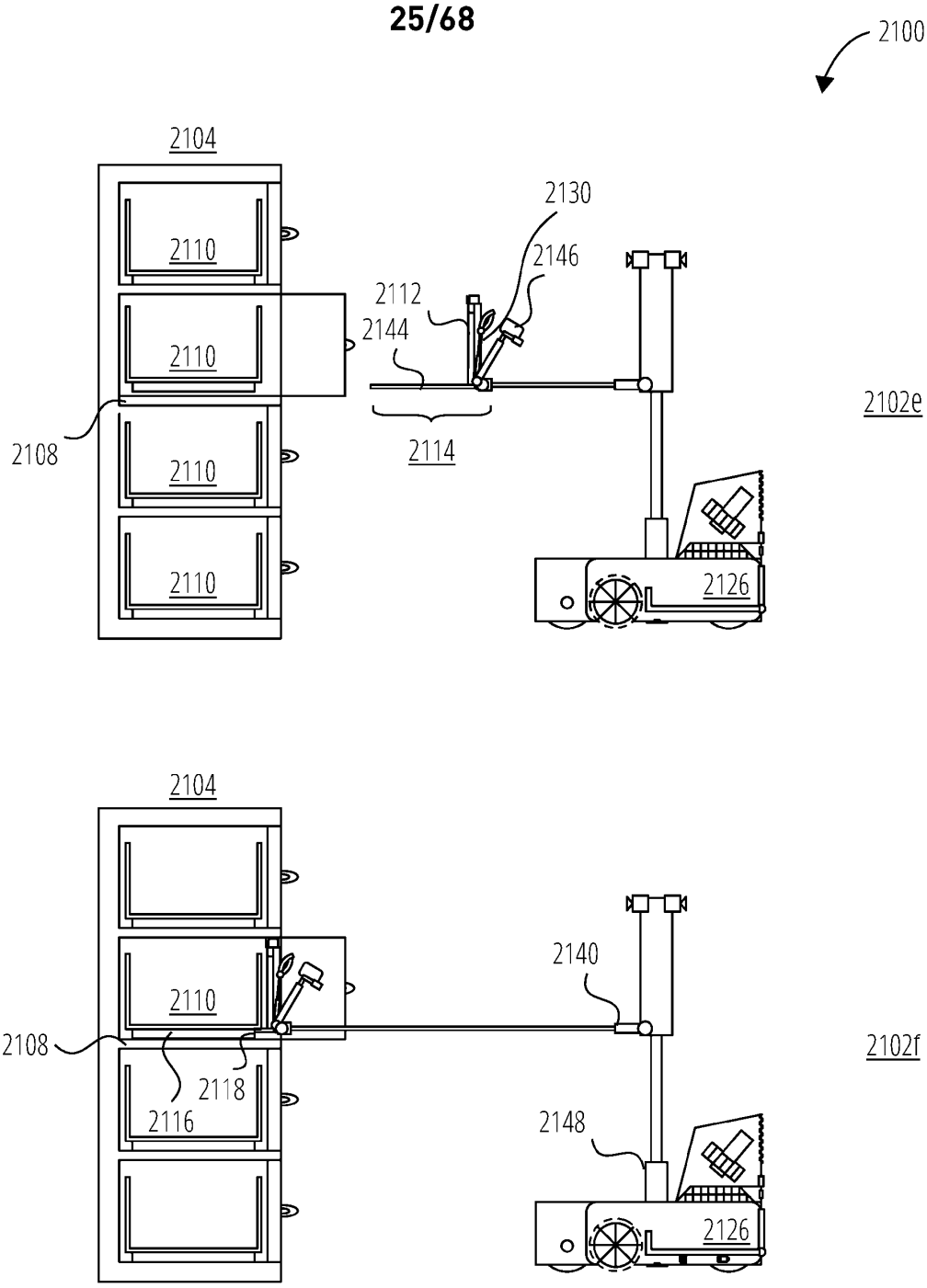

2100
2104
2110
2110
2110
2110
2108
2130
2146
2112
2144
2114
2102e
2126
2104
2110
2108
2118
2116
2140
2102f
2148
2126

FIG. 21C

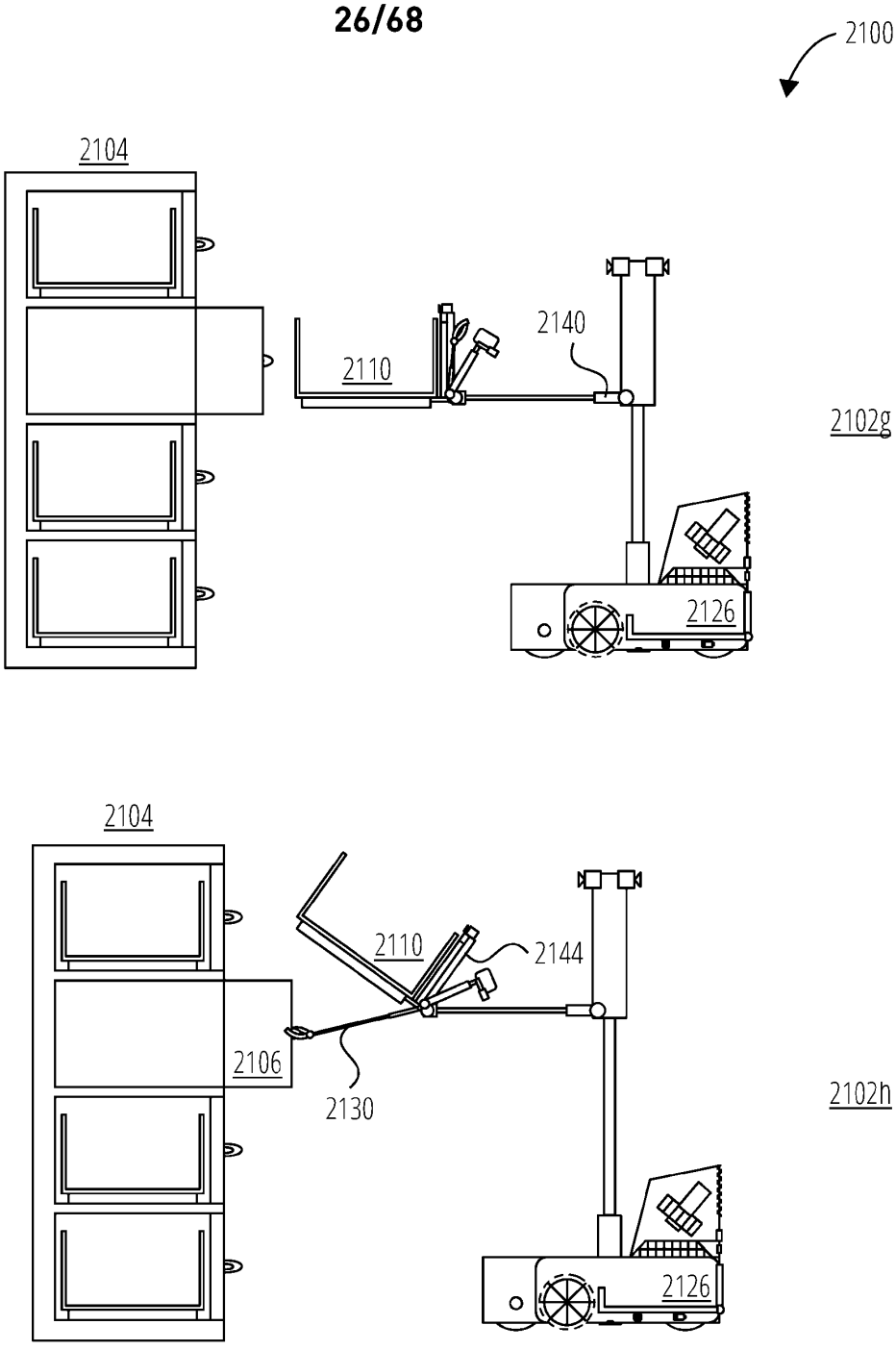

2100
2104
2110
2140
2102g
2126
2104
2110
2144
2106
2130
2102h
2126

FIG. 21D

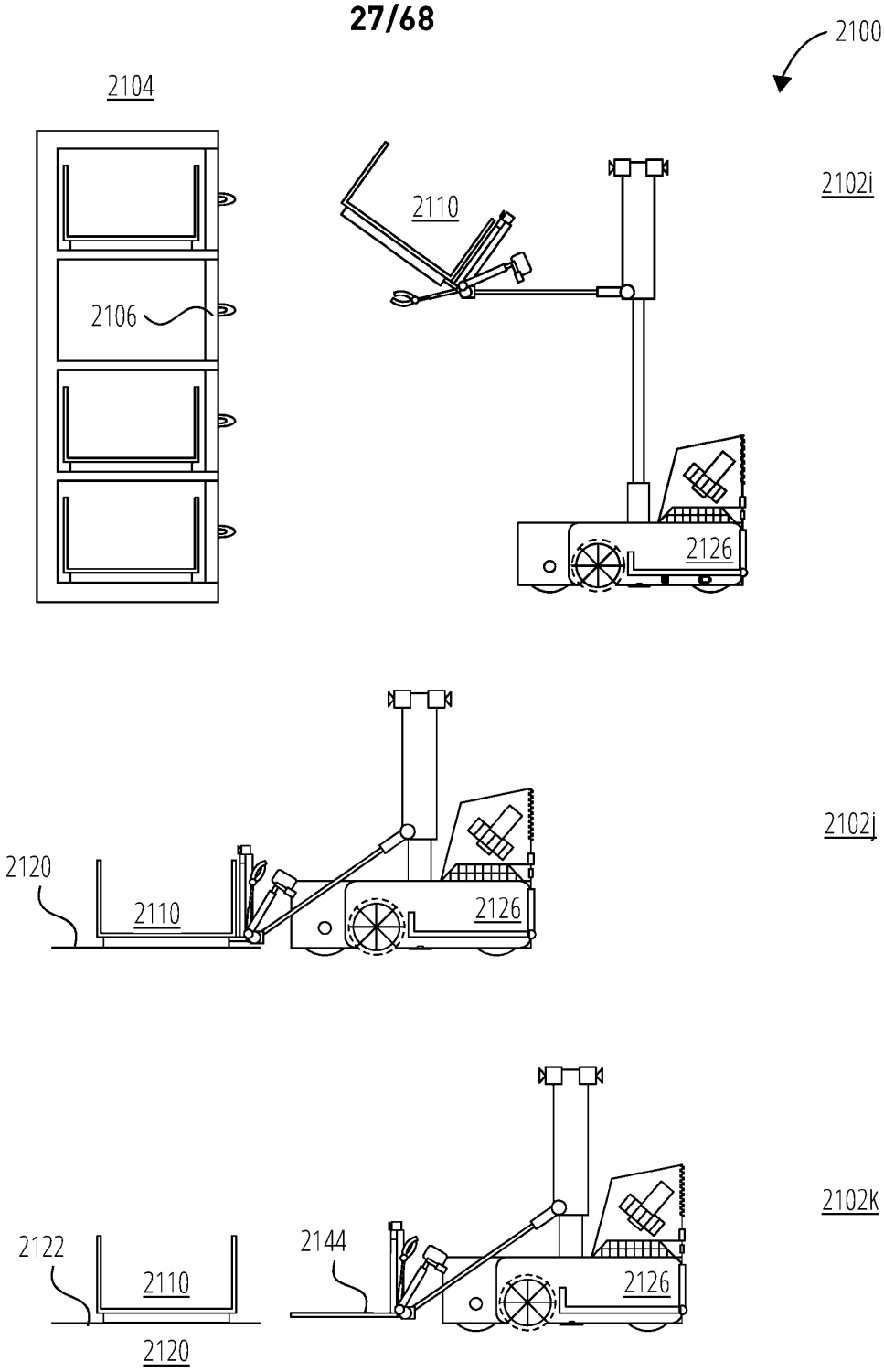

2100
2104
2106
2110
2102i
2126
2120
2110
2126
2102j
2122
2110
2120
2144
2126
2102K

FIG. 21E

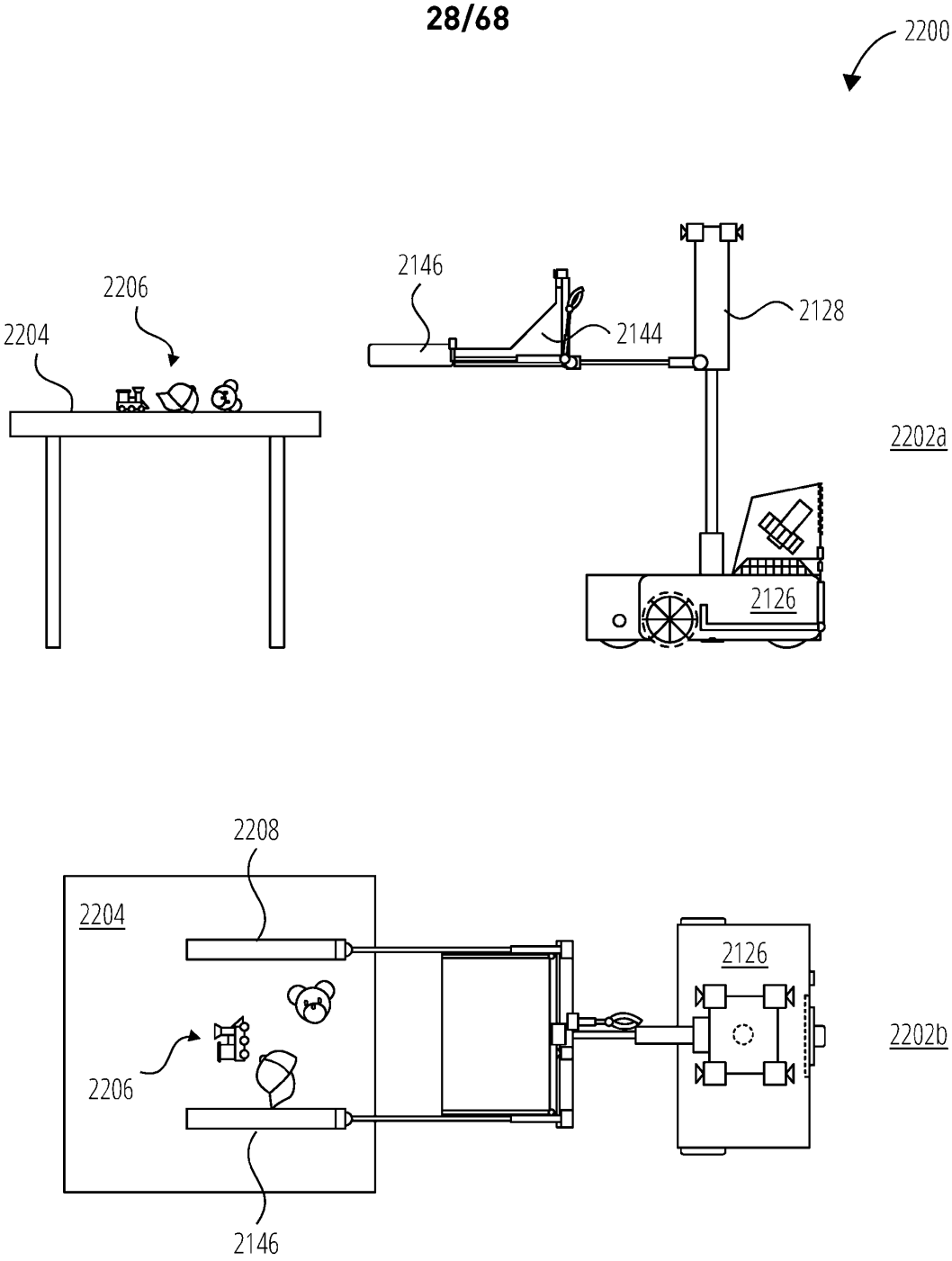

2200
2206
2204
2146
2144
2128
2202a
2126
2208
2204
2126
2206
2202b
2146

FIG. 22A

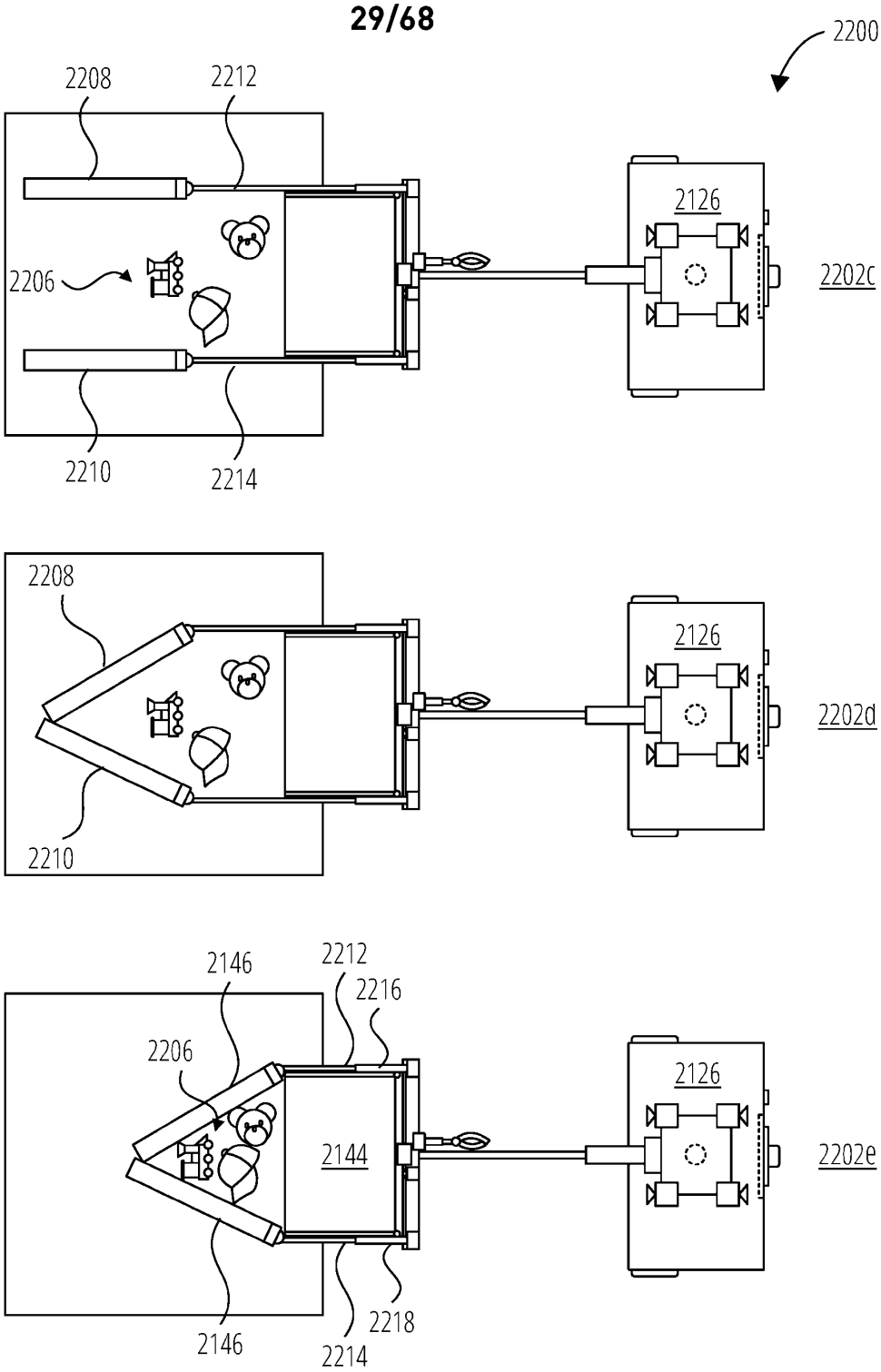

2200
2208
2212
2126
2206
2202c
2210
2214
2208
2126
2202d
2210
2146
2212
2216
2206
2126
2144
2202e
2146
2218
2214

FIG. 22B

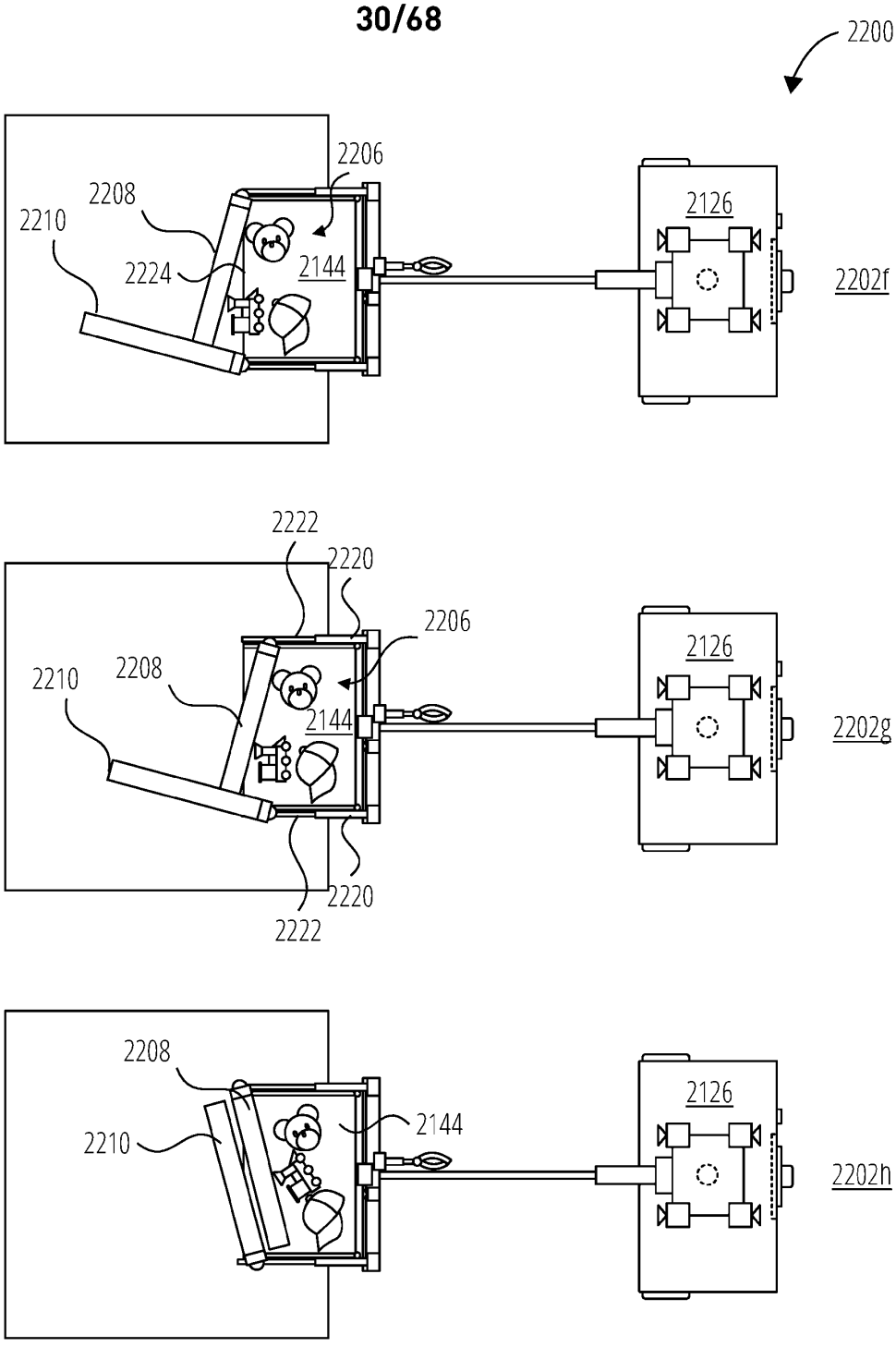

2200
2206
2208
2210
2224
2144
2126
2202f
2222
2220
2206
2210
2208
2144
2126
2202g
2220
2222
2208
2210
2144
2126
2202h

FIG. 22C

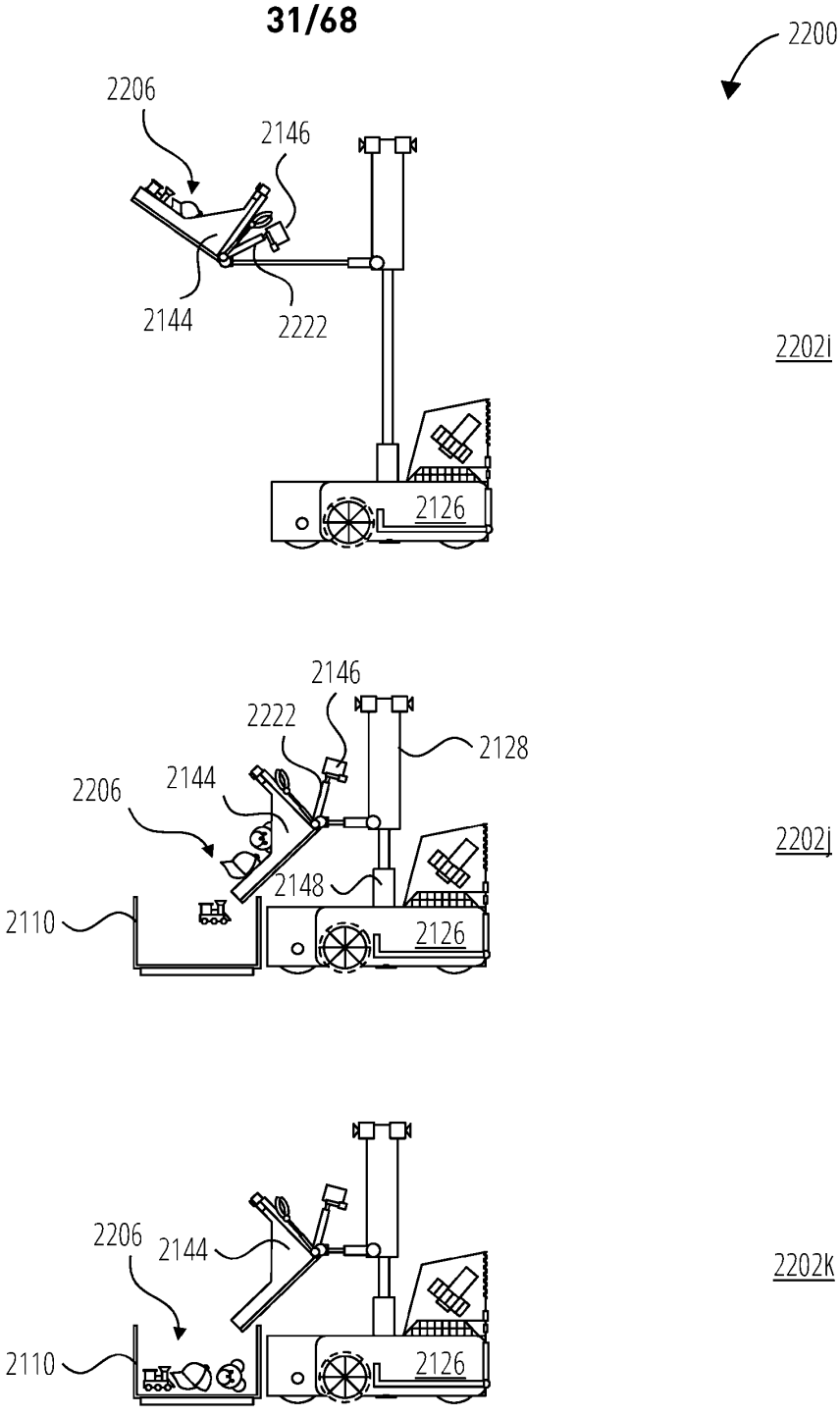

2200
2206
2146
2144
2222
2126
2202i
2146
2222
2128
2206
2144
2148
2110
2126
2202j
2206
2144
2110
2126
2202K

FIG. 22D

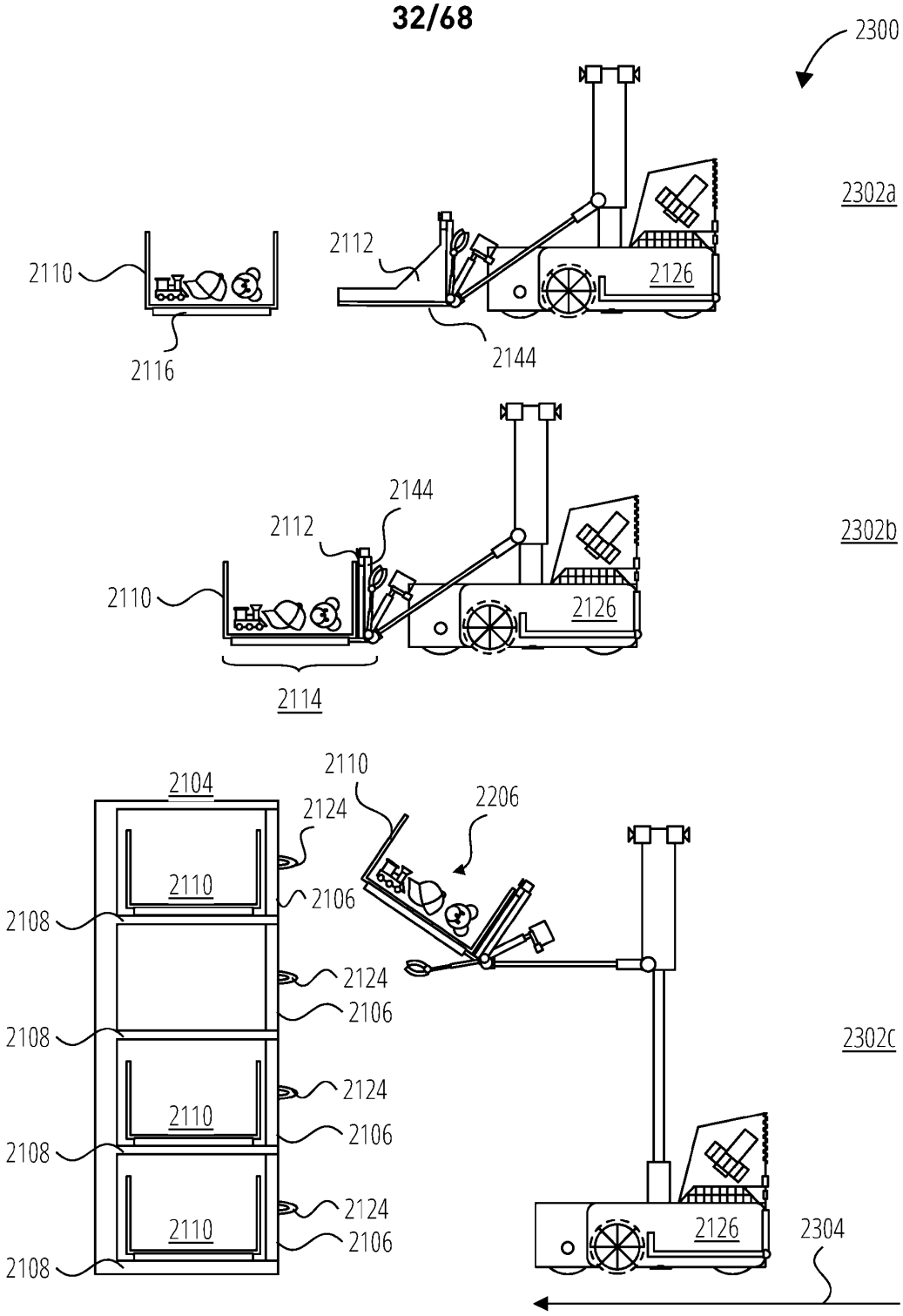

2300
2302a
2110
2112
2126
2116
2144
2144
2112
2302b
2110
2126
2114
2104
2110
2124
2206
2110
2106
2108
2124
2106
2108
2302c
2124
2110
2106
2108
2124
2110
2106
2108
2126
2304

FIG. 23A

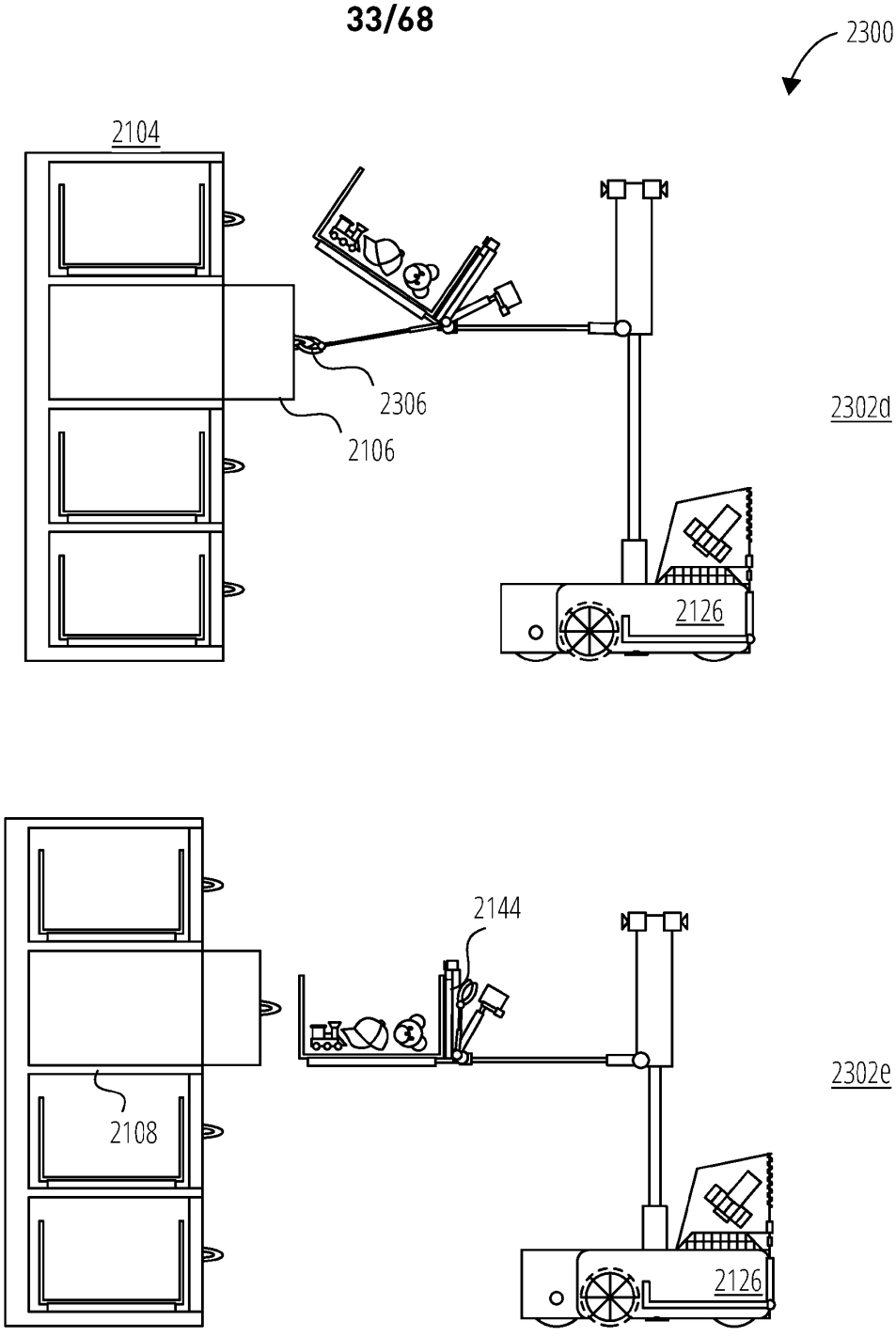


FIG. 23B

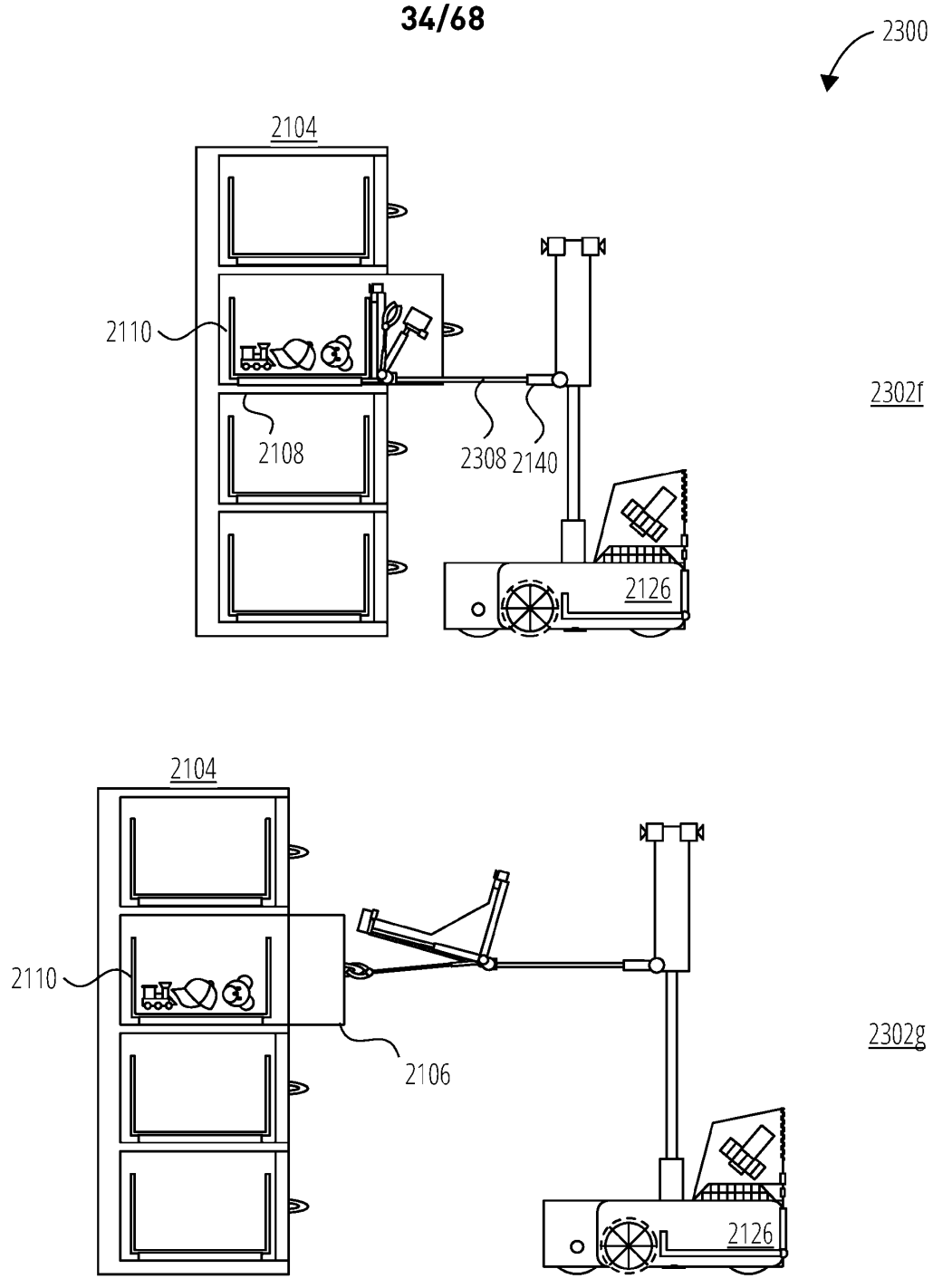

2300
2104
2110
2108
2308
2140
2126
2302f
2104
2110
2106
2126
2302g

FIG. 23C

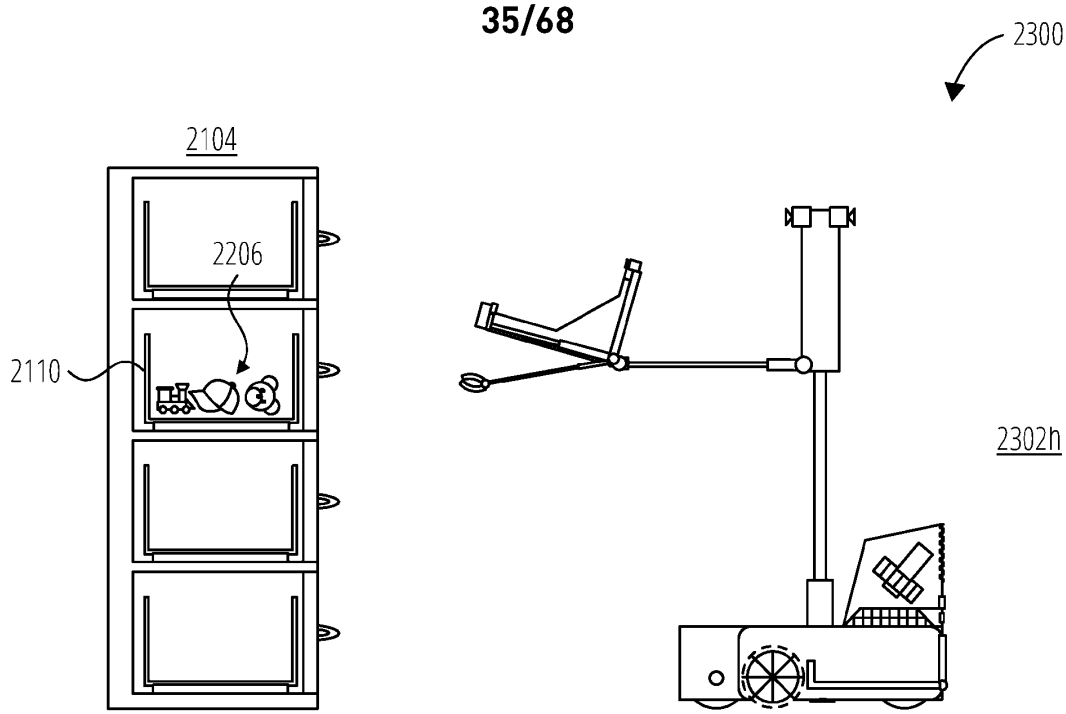


FIG. 23D

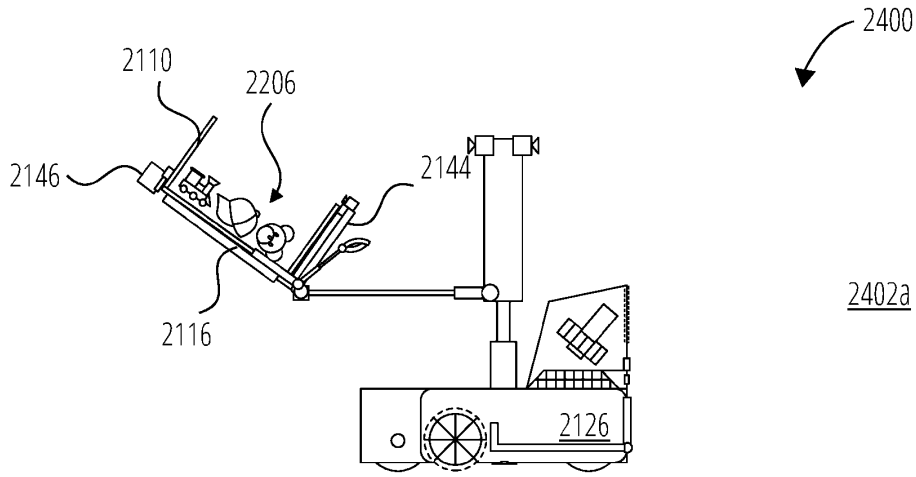


FIG. 24A

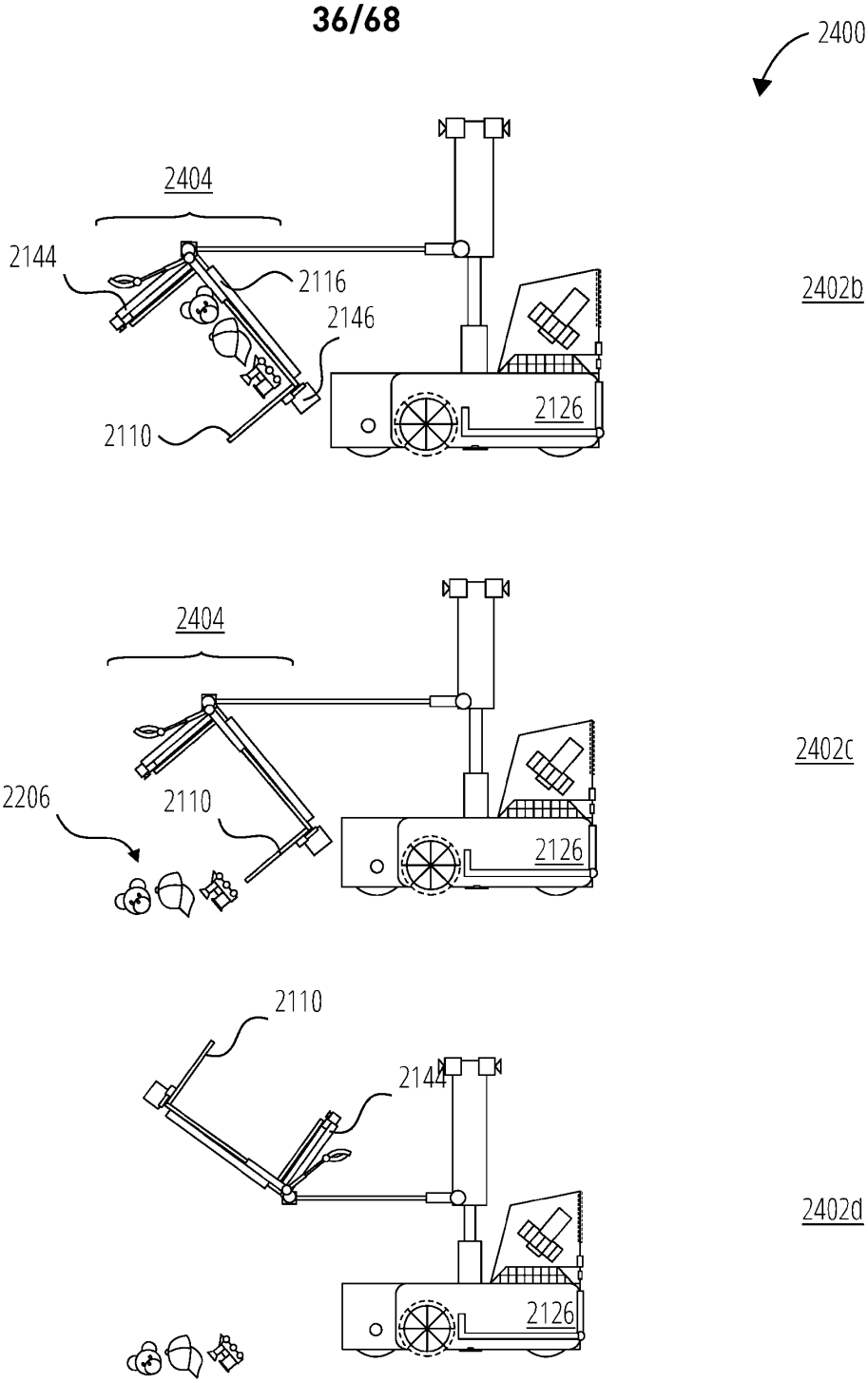

2400
2404
2144
2116
2146
2110
2126
2402b
2404
2206
2110
2126
2402c
2110
2144
2126
2402d

FIG. 24B

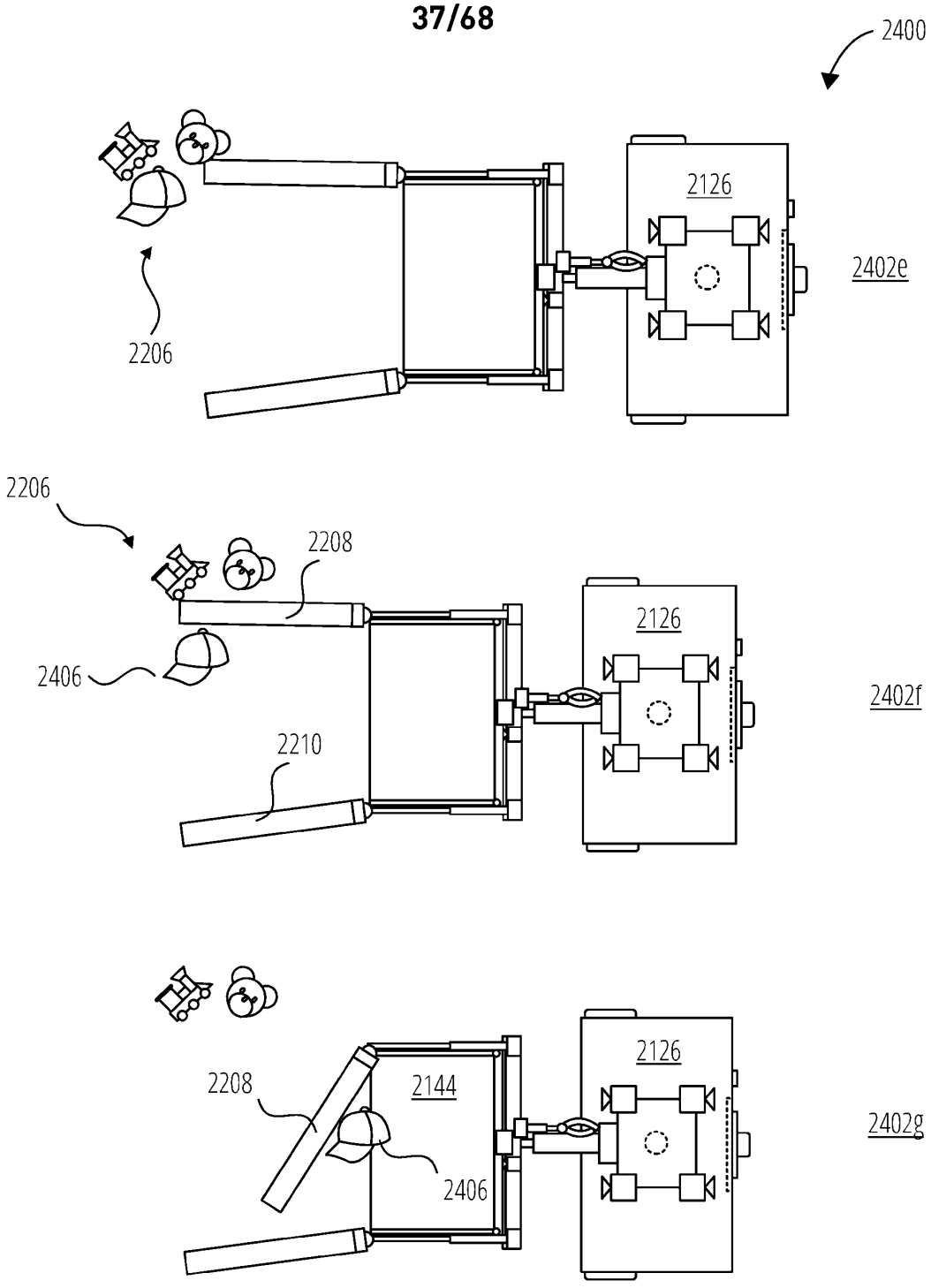

2400
2126
2402e
2206
2206
2208
2406
2126
2402f
2210
2208
2144
2126
2406
2402g

FIG. 24C

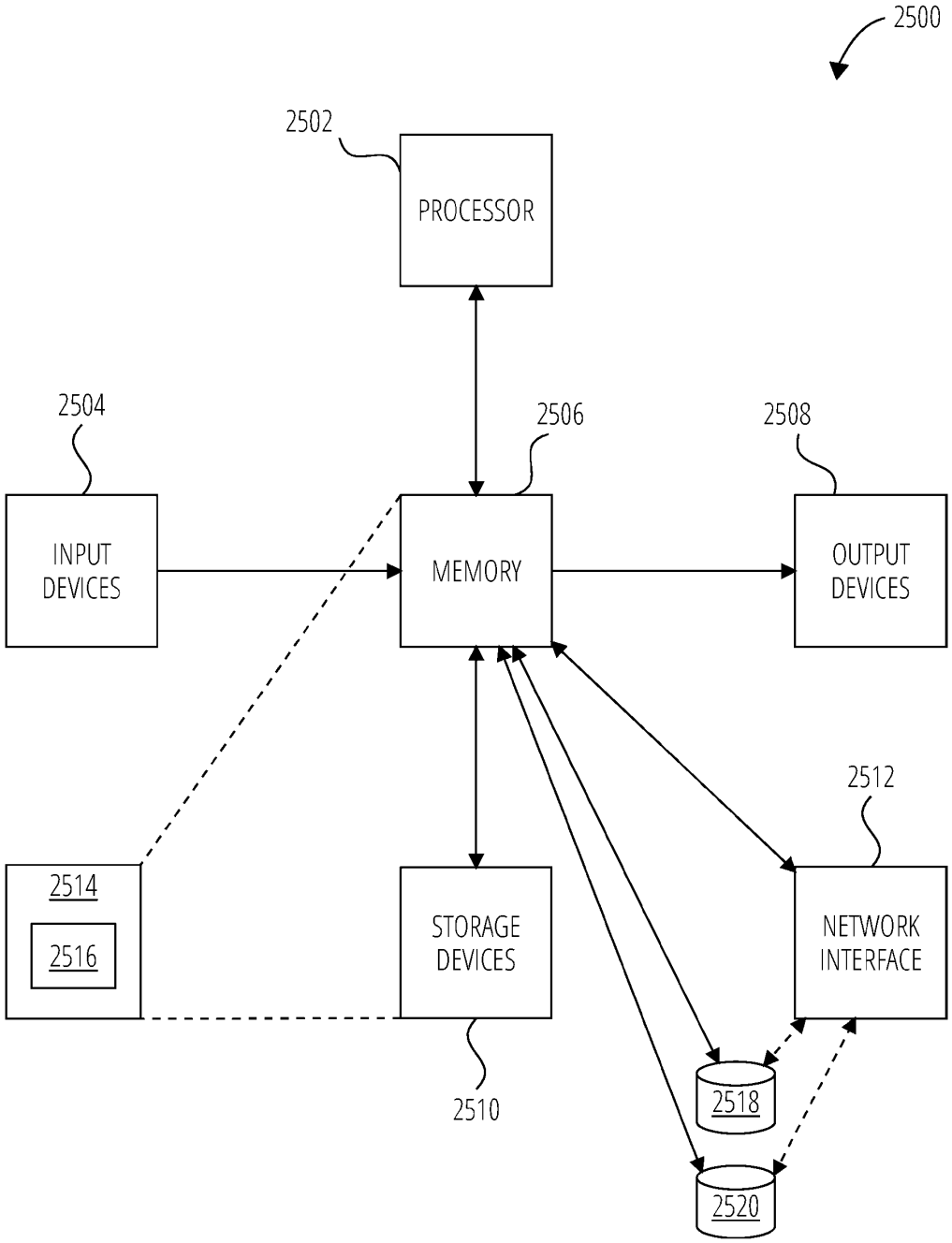

2500
2502
PROCESSOR
2504
INPUT DEVICES
2506
MEMORY
2508
OUTPUT DEVICES
2512
NETWORK INTERFACE
2514
2516
STORAGE DEVICES
2510
2518
2520

FIG. 25

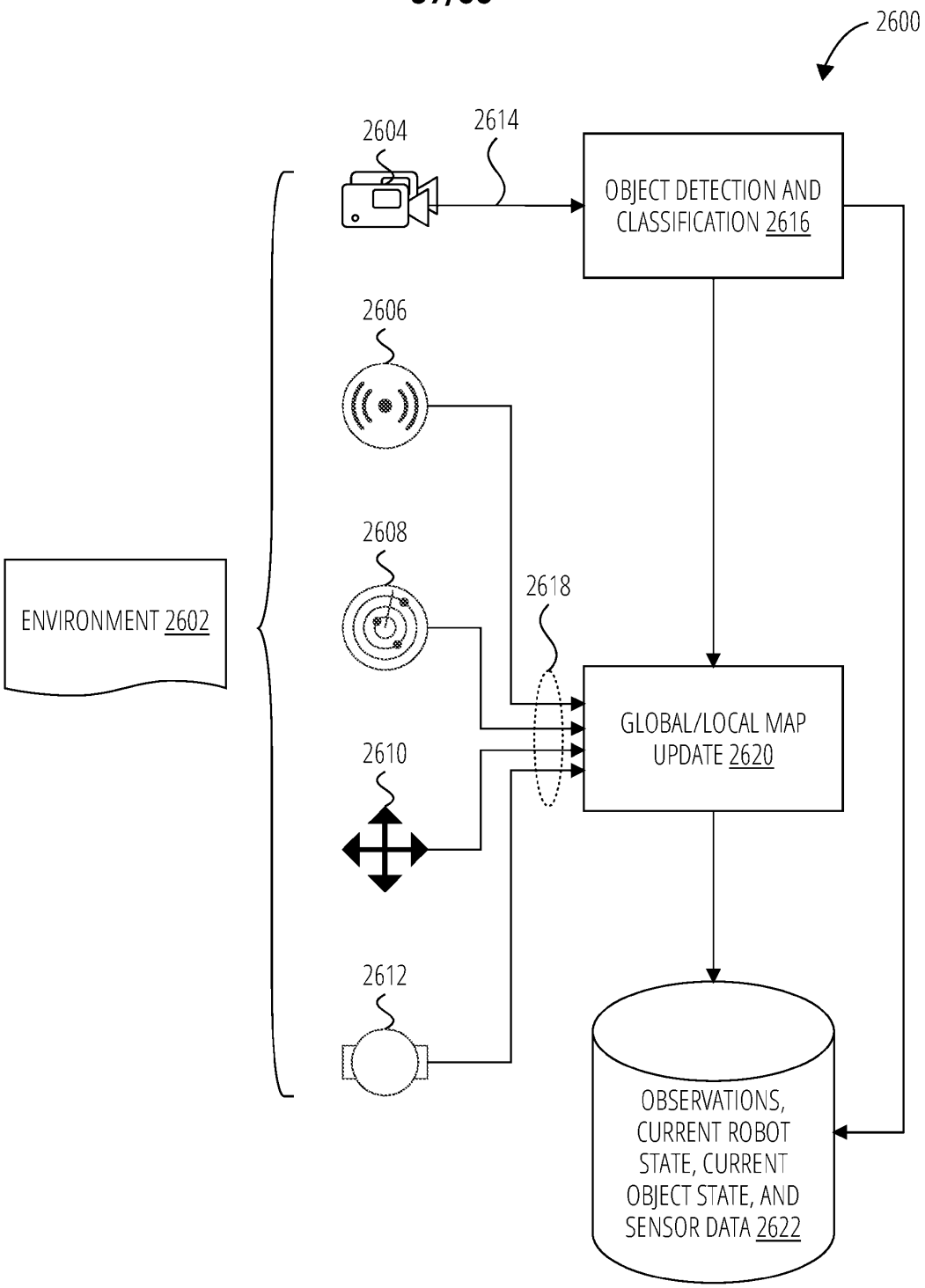

2600
2604
2614
OBJECT DETECTION AND CLASSIFICATION 2616
2606
2608
2618
ENVIRONMENT 2602
GLOBAL/LOCAL MAP UPDATE 2620
2610
2612
OBSERVATIONS, CURRENT ROBOT STATE, CURRENT OBJECT STATE, AND SENSOR DATA 2622

FIG. 26

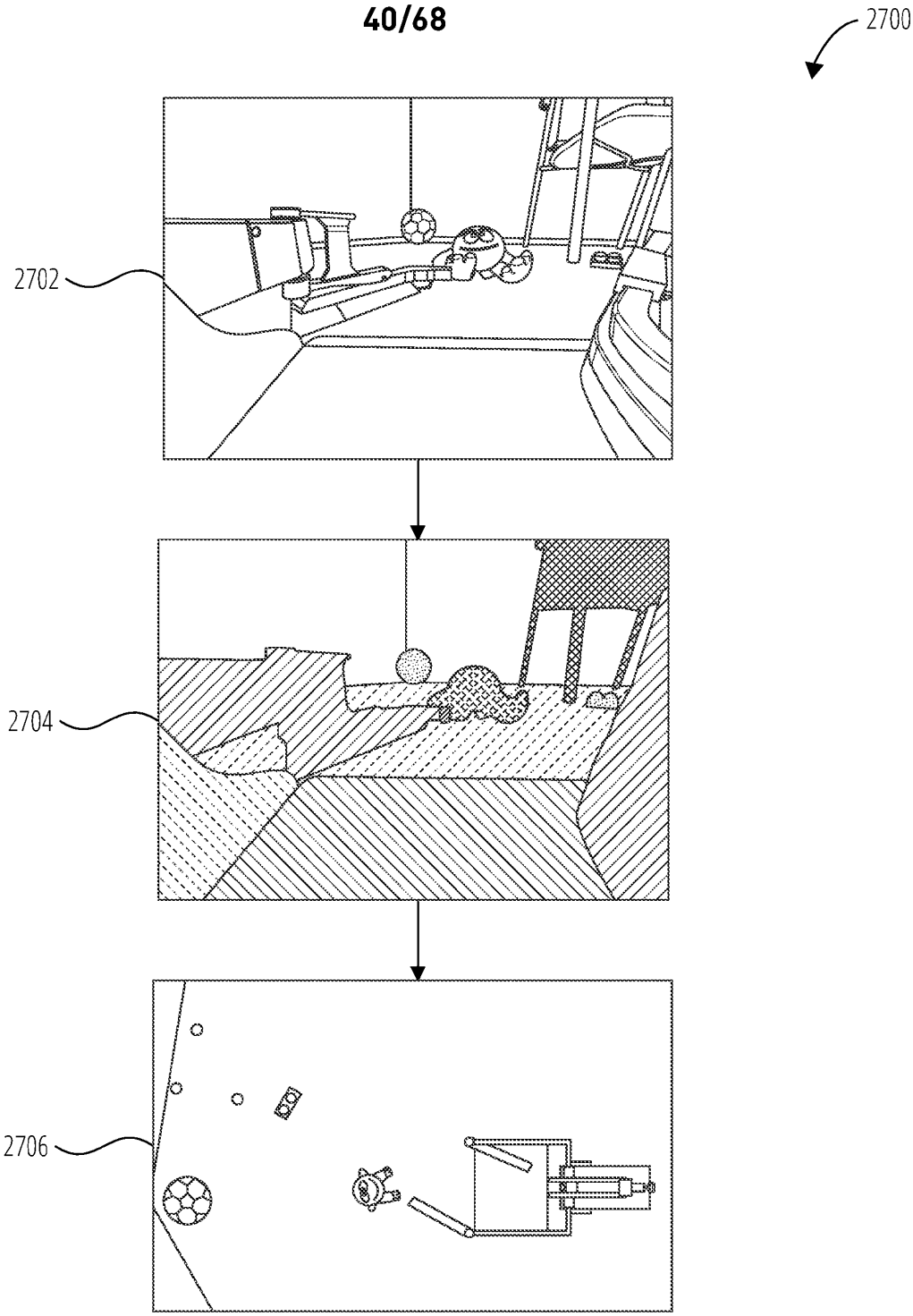


FIG. 27

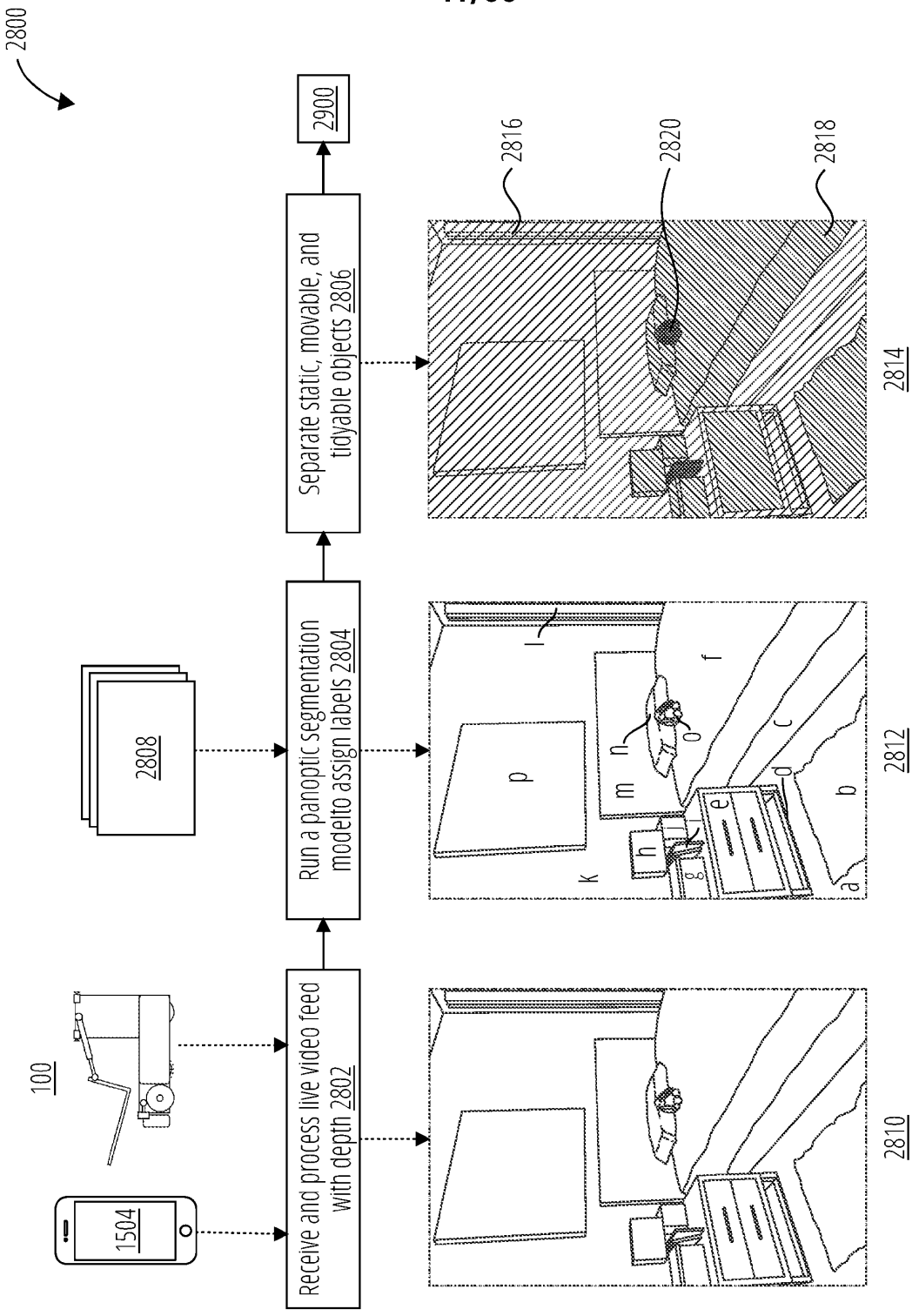

2800
100
1504
Receive and process live video feed with depth 2802
2808
Run a panoptic segmentation modelto assign labels 2804
Separate static, movable, and tidyable objects 2806
2900
2810
2812
2814
2816
2820
2818

FIG. 28

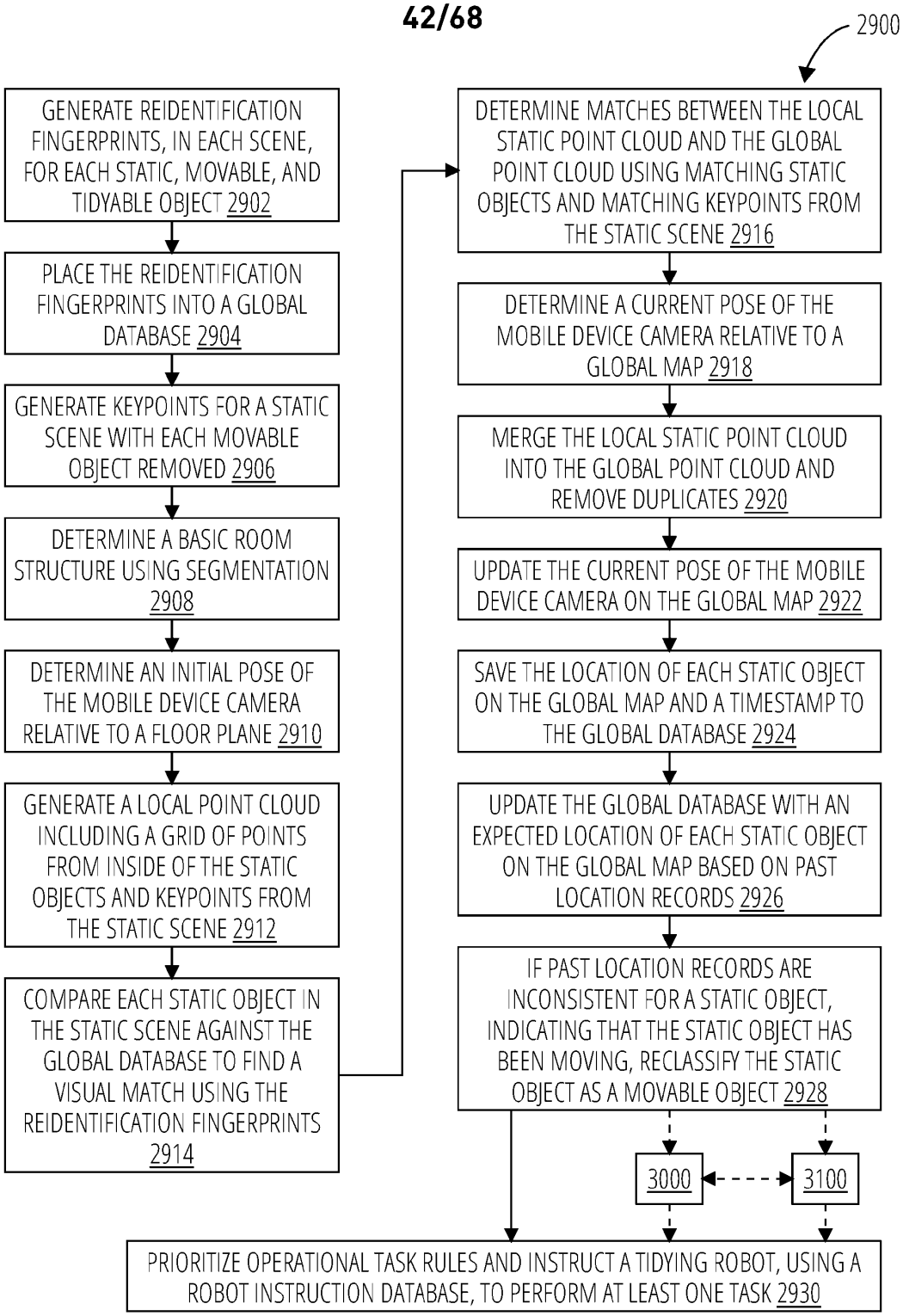

2900
GENERATE REIDENTIFICATION FINGERPRINTS, IN EACH SCENE, FOR EACH STATIC, MOVABLE, AND TIDYABLE OBJECT 2902
PLACE THE REIDENTIFICATION FINGERPRINTS INTO A GLOBAL DATABASE 2904
GENERATE KEYPOINTS FOR A STATIC SCENE WITH EACH MOVABLE OBJECT REMOVED 2906
DETERMINE A BASIC ROOM STRUCTURE USING SEGMENTATION 2908
DETERMINE AN INITIAL POSE OF THE MOBILE DEVICE CAMERA RELATIVE TO A FLOOR PLANE 2910
GENERATE A LOCAL POINT CLOUD INCLUDING A GRID OF POINTS FROM INSIDE OF THE STATIC OBJECTS AND KEYPOINTS FROM THE STATIC SCENE 2912
COMPARE EACH STATIC OBJECT IN THE STATIC SCENE AGAINST THE GLOBAL DATABASE TO FIND A VISUAL MATCH USING THE REIDENTIFICATION FINGERPRINTS 2914
DETERMINE MATCHES BETWEEN THE LOCAL STATIC POINT CLOUD AND THE GLOBAL POINT CLOUD USING MATCHING STATIC OBJECTS AND MATCHING KEYPOINTS FROM THE STATIC SCENE 2916
DETERMINE A CURRENT POSE OF THE MOBILE DEVICE CAMERA RELATIVE TO A GLOBAL MAP 2918
MERGE THE LOCAL STATIC POINT CLOUD INTO THE GLOBAL POINT CLOUD AND REMOVE DUPLICATES 2920
UPDATE THE CURRENT POSE OF THE MOBILE DEVICE CAMERA ON THE GLOBAL MAP 2922
SAVE THE LOCATION OF EACH STATIC OBJECT ON THE GLOBAL MAP AND A TIMESTAMP TO THE GLOBAL DATABASE 2924
UPDATE THE GLOBAL DATABASE WITH AN EXPECTED LOCATION OF EACH STATIC OBJECT ON THE GLOBAL MAP BASED ON PAST LOCATION RECORDS 2926
IF PAST LOCATION RECORDS ARE INCONSISTENT FOR A STATIC OBJECT, INDICATING THAT THE STATIC OBJECT HAS BEEN MOVING, RECLASSIFY THE STATIC OBJECT AS A MOVABLE OBJECT 2928
3000
3100
PRIORITIZE OPERATIONAL TASK RULES AND INSTRUCT A TIDYING ROBOT, USING A ROBOT INSTRUCTION DATABASE, TO PERFORM AT LEAST ONE TASK 2930

FIG. 29

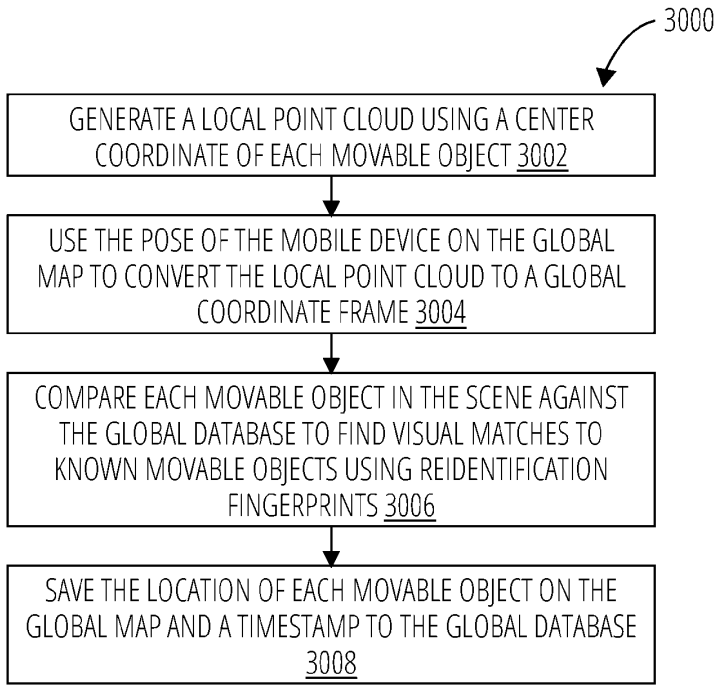

3000
GENERATE A LOCAL POINT CLOUD USING A CENTER COORDINATE OF EACH MOVABLE OBJECT 3002
USE THE POSE OF THE MOBILE DEVICE ON THE GLOBAL MAP TO CONVERT THE LOCAL POINT CLOUD TO A GLOBAL COORDINATE FRAME 3004
COMPARE EACH MOVABLE OBJECT IN THE SCENE AGAINST THE GLOBAL DATABASE TO FIND VISUAL MATCHES TO KNOWN MOVABLE OBJECTS USING REIDENTIFICATION FINGERPRINTS 3006
SAVE THE LOCATION OF EACH MOVABLE OBJECT ON THE GLOBAL MAP AND A TIMESTAMP TO THE GLOBAL DATABASE 3008

FIG. 30

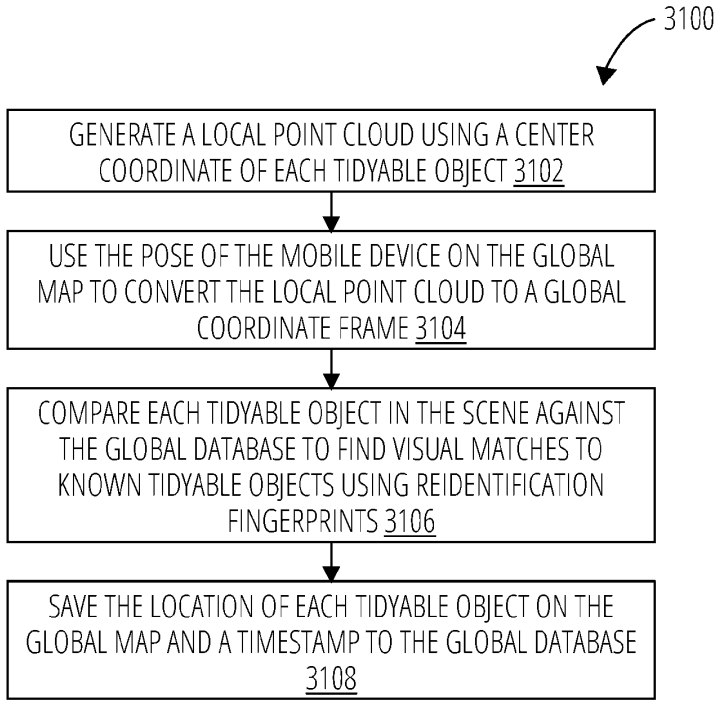

3100
GENERATE A LOCAL POINT CLOUD USING A CENTER COORDINATE OF EACH TIDYABLE OBJECT 3102
USE THE POSE OF THE MOBILE DEVICE ON THE GLOBAL MAP TO CONVERT THE LOCAL POINT CLOUD TO A GLOBAL COORDINATE FRAME 3104
COMPARE EACH TIDYABLE OBJECT IN THE SCENE AGAINST THE GLOBAL DATABASE TO FIND VISUAL MATCHES TO KNOWN TIDYABLE OBJECTS USING REIDENTIFICATION FINGERPRINTS 3106
SAVE THE LOCATION OF EACH TIDYABLE OBJECT ON THE GLOBAL MAP AND A TIMESTAMP TO THE GLOBAL DATABASE 3108

FIG. 31

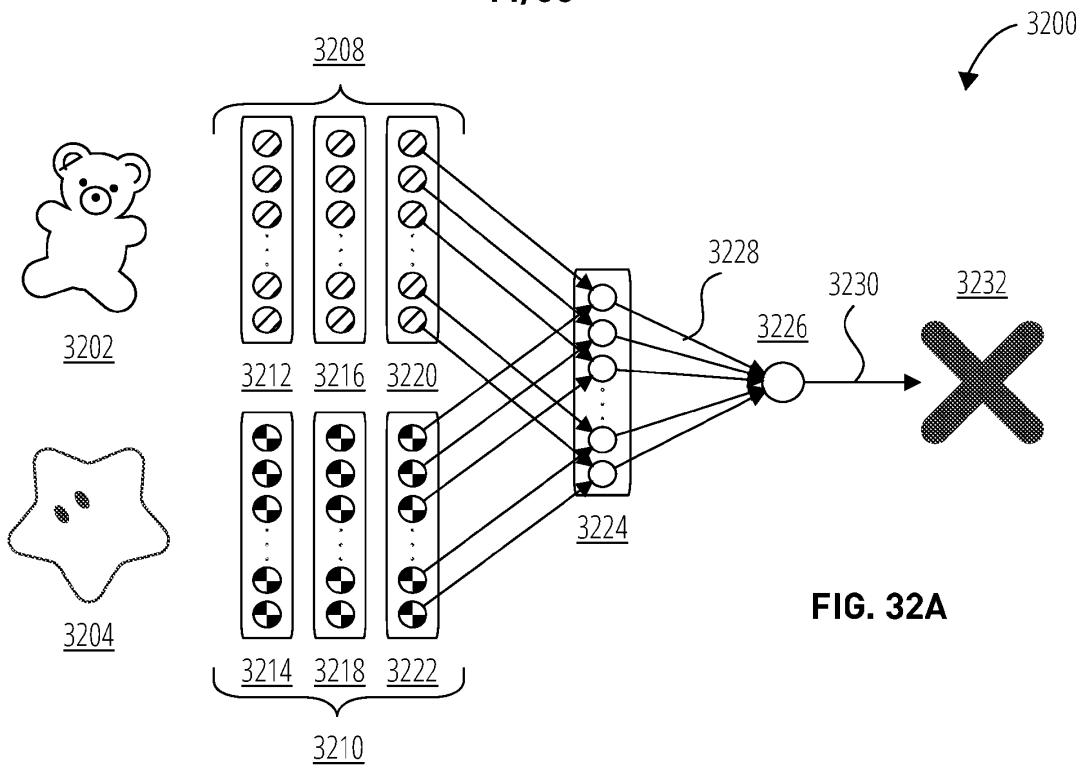


FIG. 32A

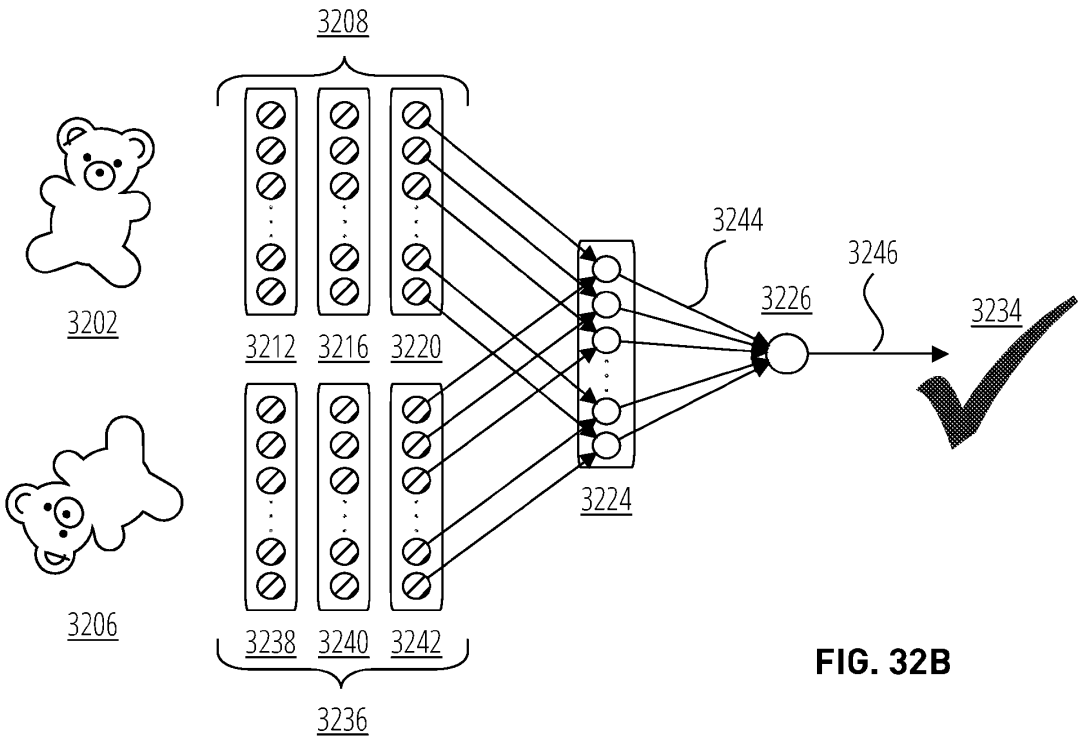


FIG. 32B

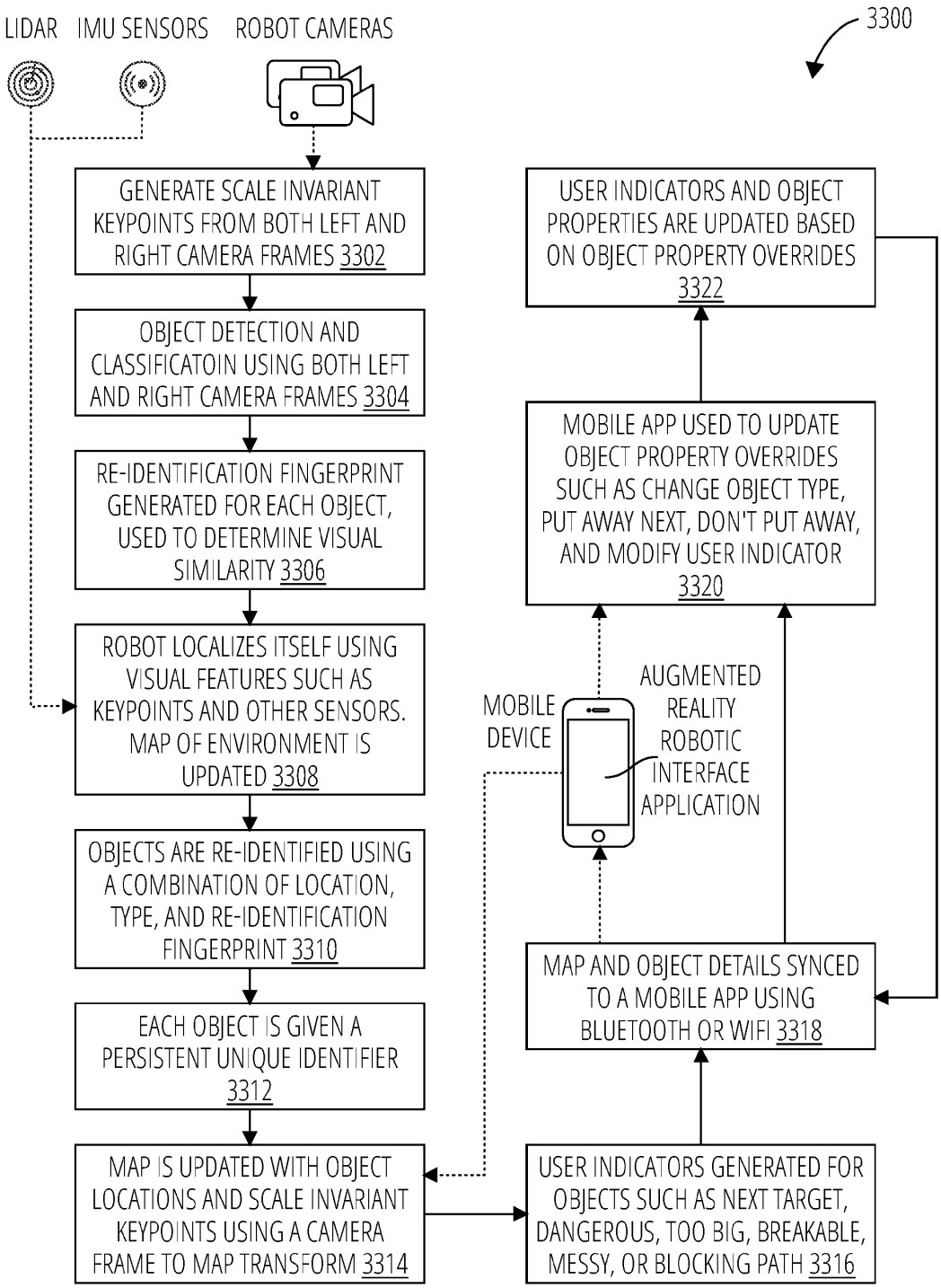

LIDAR
IMU SENSORS
ROBOT CAMERAS
3300
GENERATE SCALE INVARIANT KEYPOINTS FROM BOTH LEFT AND RIGHT CAMERA FRAMES 3302
OBJECT DETECTION AND CLASSIFICATOIN USING BOTH LEFT AND RIGHT CAMERA FRAMES 3304
RE-IDENTIFICATION FINGERPRINT GENERATED FOR EACH OBJECT, USED TO DETERMINE VISUAL SIMILARITY 3306
ROBOT LOCALIZES ITSELF USING VISUAL FEATURES SUCH AS KEYPOINTS AND OTHER SENSORS. MAP OF ENVIRONMENT IS UPDATED 3308
OBJECTS ARE RE-IDENTIFIED USING A COMBINATION OF LOCATION, TYPE, AND RE-IDENTIFICATION FINGERPRINT 3310
EACH OBJECT IS GIVEN A PERSISTENT UNIQUE IDENTIFIER 3312
MAP IS UPDATED WITH OBJECT LOCATIONS AND SCALE INVARIANT KEYPOINTS USING A CAMERA FRAME TO MAP TRANSFORM 3314
USER INDICATORS GENERATED FOR OBJECTS SUCH AS NEXT TARGET, DANGEROUS, TOO BIG, BREAKABLE, MESSY, OR BLOCKING PATH 3316
MAP AND OBJECT DETAILS SYNCED TO A MOBILE APP USING BLUETOOTH OR WIFI 3318
MOBILE DEVICE
AUGMENTED REALITY ROBOTIC INTERFACE APPLICATION
MOBILE APP USED TO UPDATE OBJECT PROPERTY OVERRIDES SUCH AS CHANGE OBJECT TYPE, PUT AWAY NEXT, DON'T PUT AWAY, AND MODIFY USER INDICATOR 3320
USER INDICATORS AND OBJECT PROPERTIES ARE UPDATED BASED ON OBJECT PROPERTY OVERRIDES 3322

FIG. 33

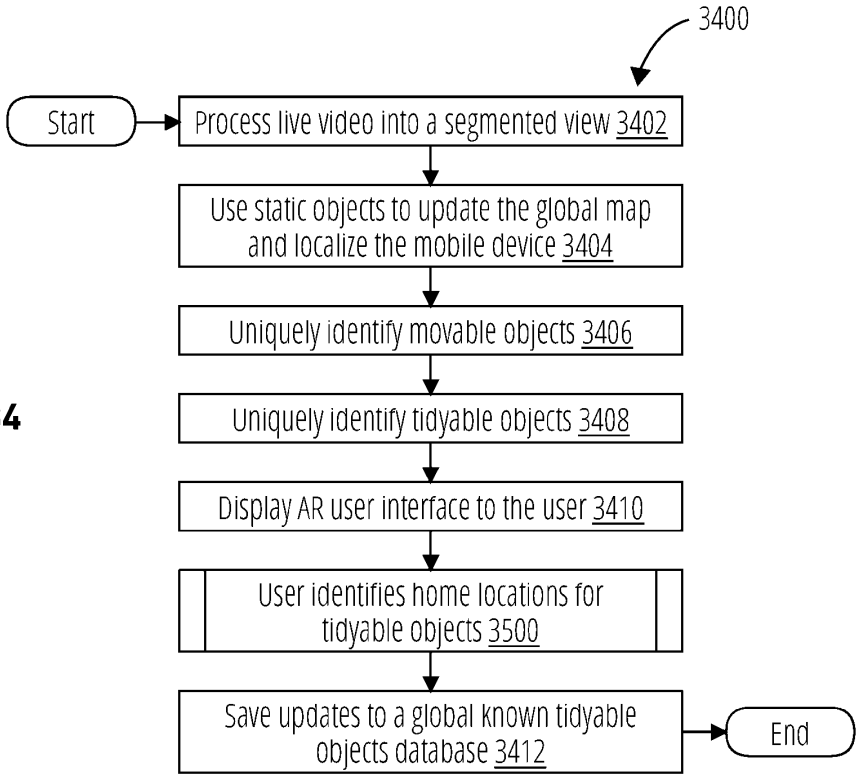

3400
Start
Process live video into a segmented view 3402
Use static objects to update the global map and localize the mobile device 3404
Uniquely identify movable objects 3406
Uniquely identify tidyable objects 3408
Display AR user interface to the user 3410
User identifies home locations for tidyable objects 3500
Save updates to a global known tidyable objects database 3412
End

FIG. 34

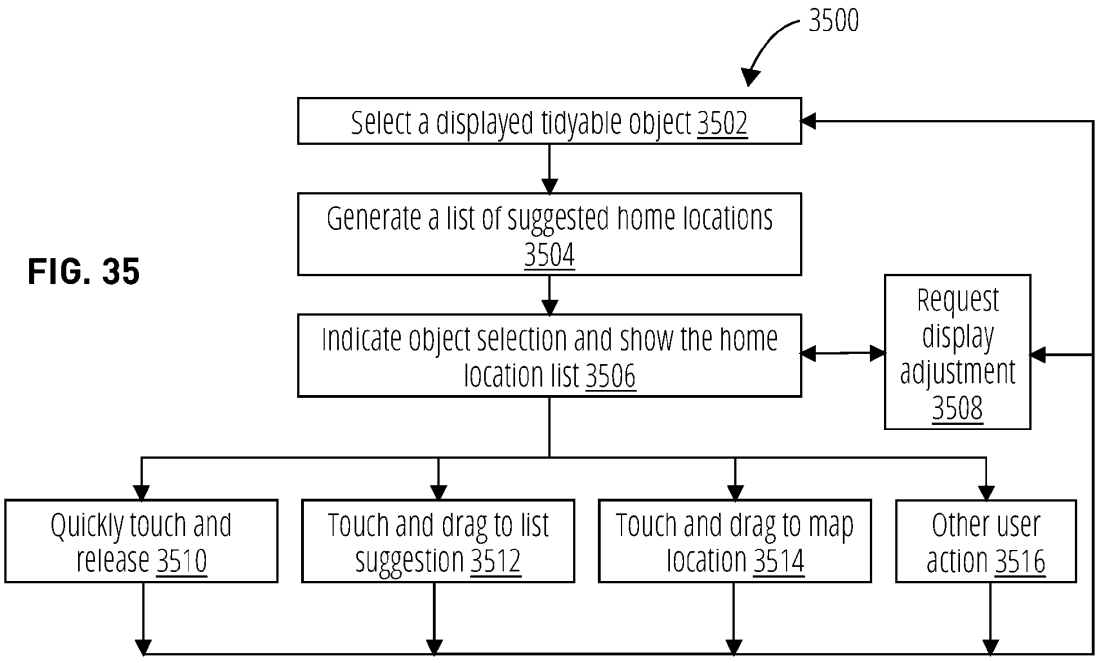

3500
Select a displayed tidyable object 3502
Generate a list of suggested home locations 3504
Indicate object selection and show the home location list 3506
Request display adjustment 3508
Quickly touch and release 3510
Touch and drag to list suggestion 3512
Touch and drag to map location 3514
Other user action 3516

FIG. 35

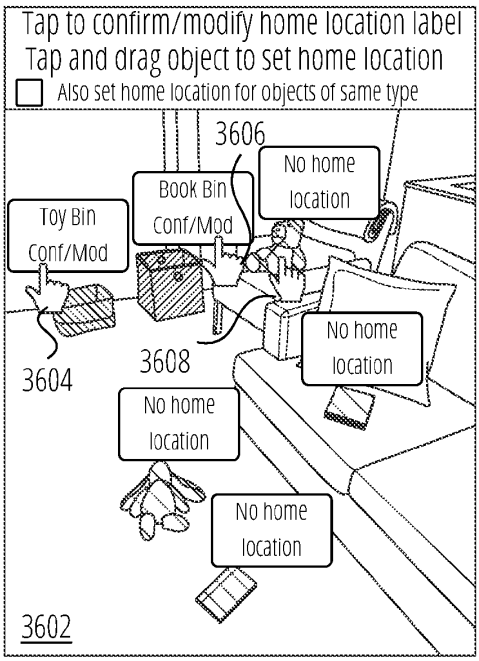


FIG. 36A

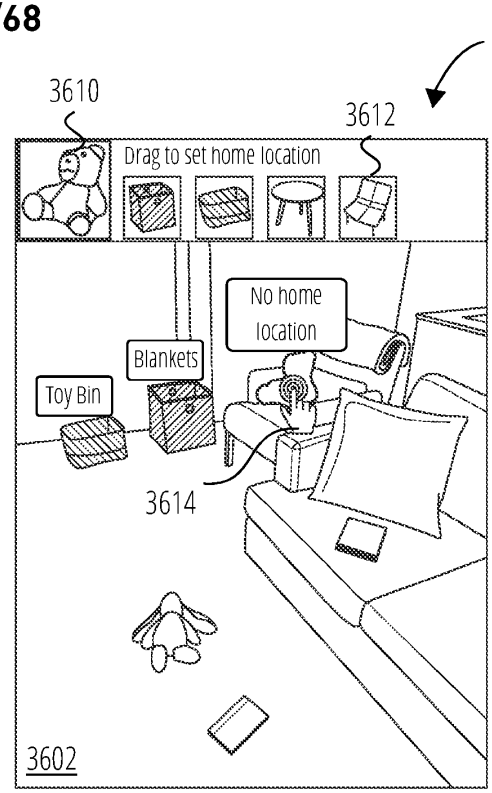


FIG. 36B

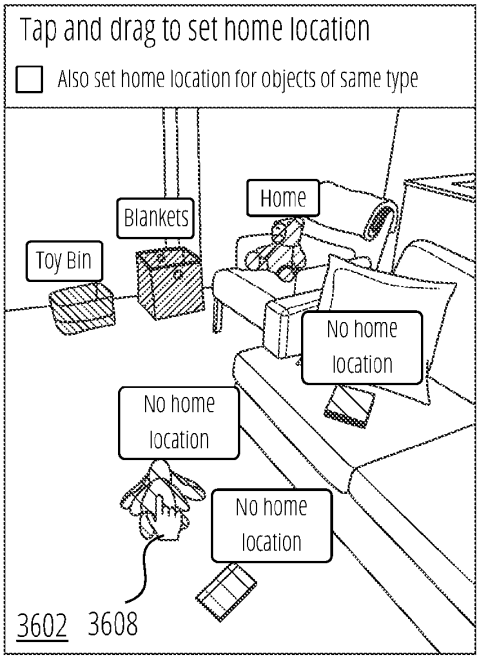


FIG. 36C

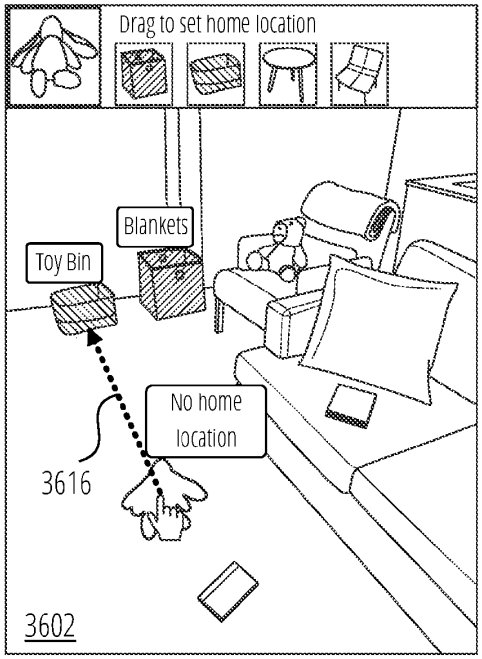


FIG. 36D

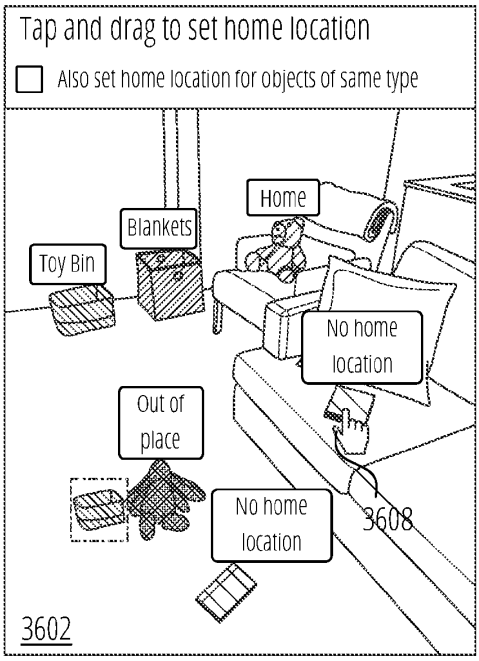


FIG. 36E

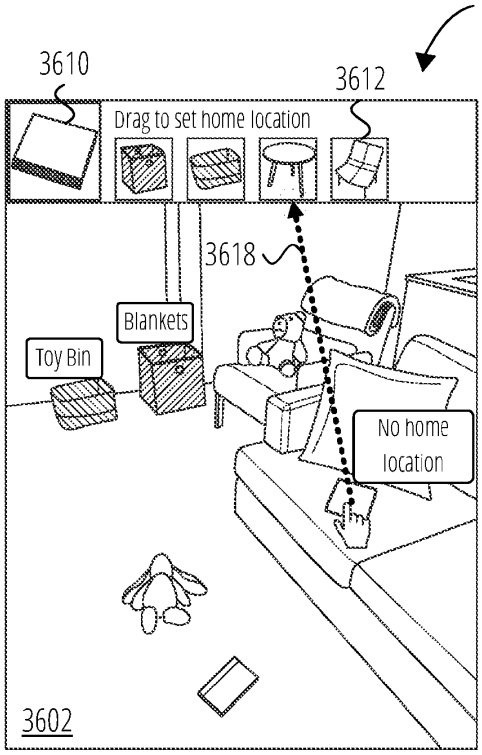


FIG. 36F

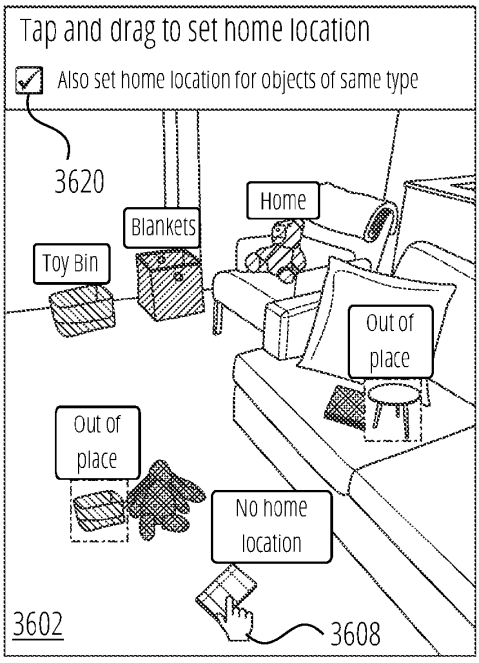


FIG. 36G

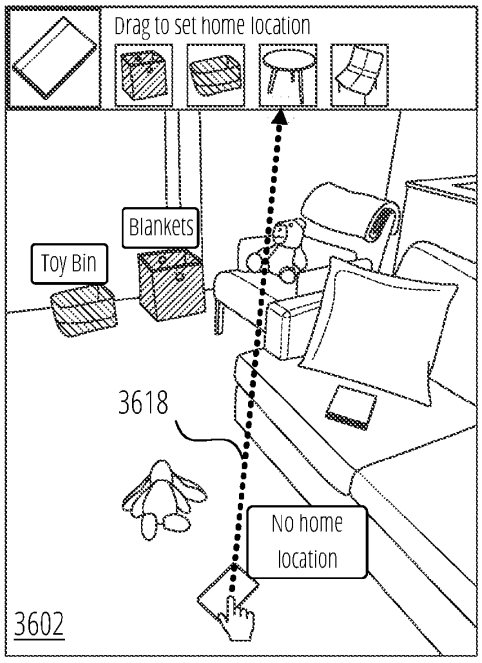


FIG. 36H

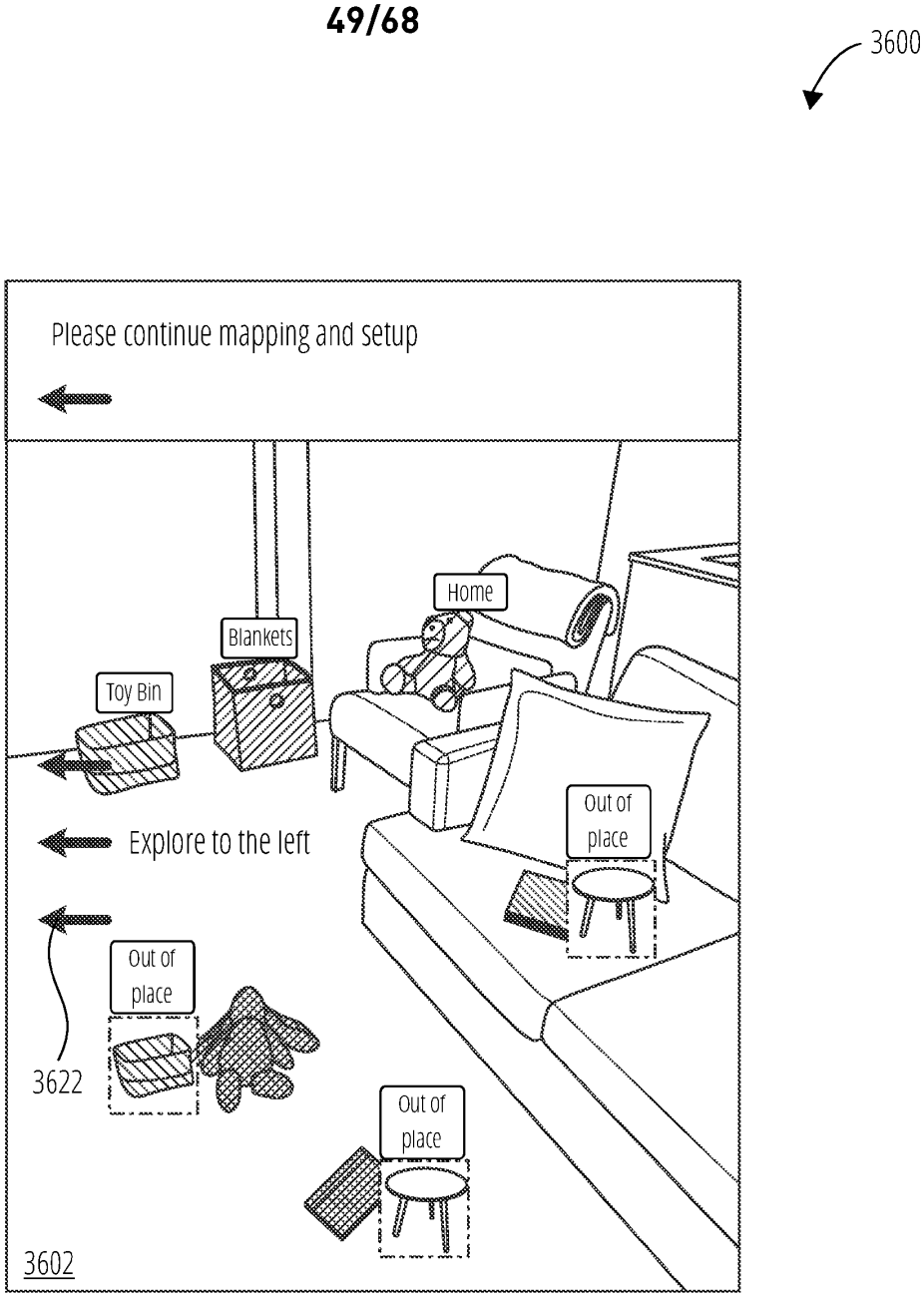

3600
Please continue mapping and setup
Home
Blankets
Toy Bin
Explore to the left
Out of place
Out of place
Out of place
3622
3602

FIG. 36I

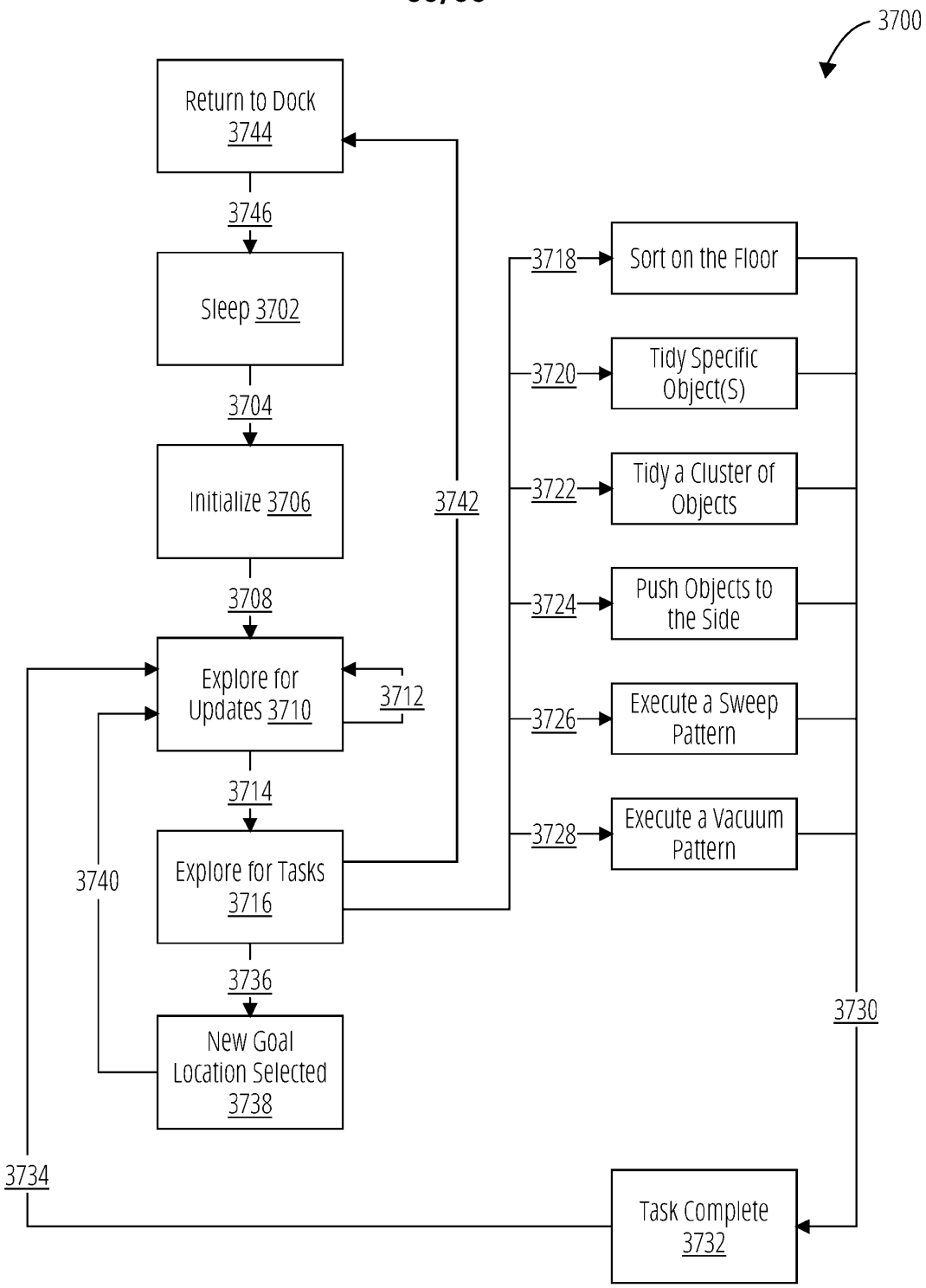

3700
Return to Dock 3744
3746
Sleep 3702
3704
Initialize 3706
3708
Explore for Updates 3710
3712
3714
Explore for Tasks 3716
3736
New Goal Location Selected 3738
3740
3742
3718
Sort on the Floor
3720
Tidy Specific Object(S)
3722
Tidy a Cluster of Objects
3724
Push Objects to the Side
3726
Execute a Sweep Pattern
3728
Execute a Vacuum Pattern
3730
3734
Task Complete 3732

FIG. 37

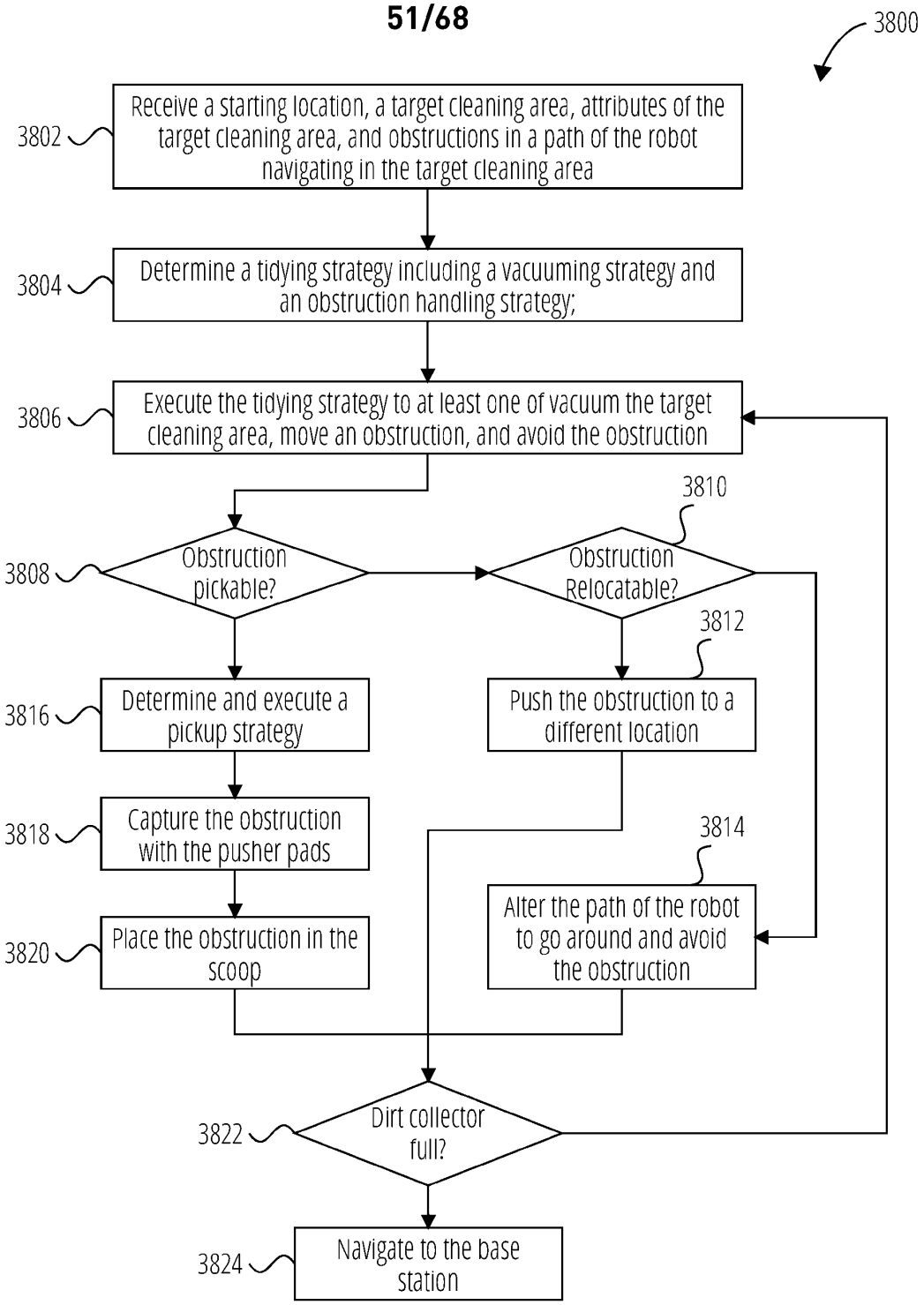

3800
3802
Receive a starting location, a target cleaning area, attributes of the target cleaning area, and obstructions in a path of the robot navigating in the target cleaning area
3804
Determine a tidying strategy including a vacuuming strategy and an obstruction handling strategy;
3806
Execute the tidying strategy to at least one of vacuum the target cleaning area, move an obstruction, and avoid the obstruction
3808
Obstruction pickable?
3810
Obstruction Relocatable?
3812
3816
Determine and execute a pickup strategy
Push the obstruction to a different location
3818
Capture the obstruction with the pusher pads
3814
3820
Place the obstruction in the scoop
Alter the path of the robot to go around and avoid the obstruction
3822
Dirt collector full?
3824
Navigate to the base station

FIG. 38

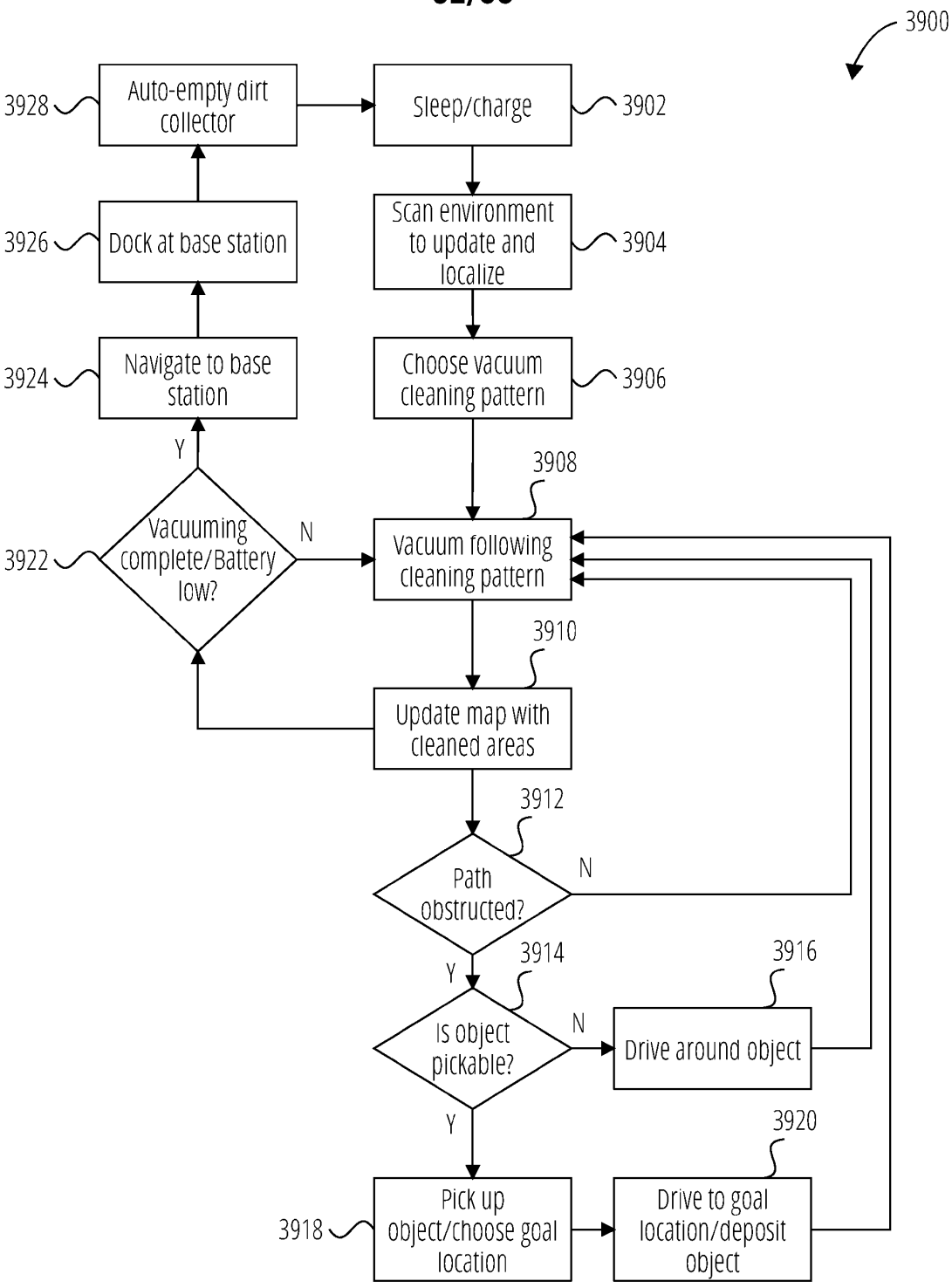

3900
Auto-empty dirt collector
3928
Sleep/charge
3902
Dock at base station
3926
Scan environment to update and localize
3904
Navigate to base station
3924
Choose vacuum cleaning pattern
3906
Y
3908
Vacuuming complete/Battery low?
3922
N
Vacuum following cleaning pattern
3910
Update map with cleaned areas
3912
Path obstructed?
N
Y
3914
3916
Is object pickable?
N
Drive around object
Y
3920
Pick up object/choose goal location
3918
Drive to goal location/deposit object

FIG. 39

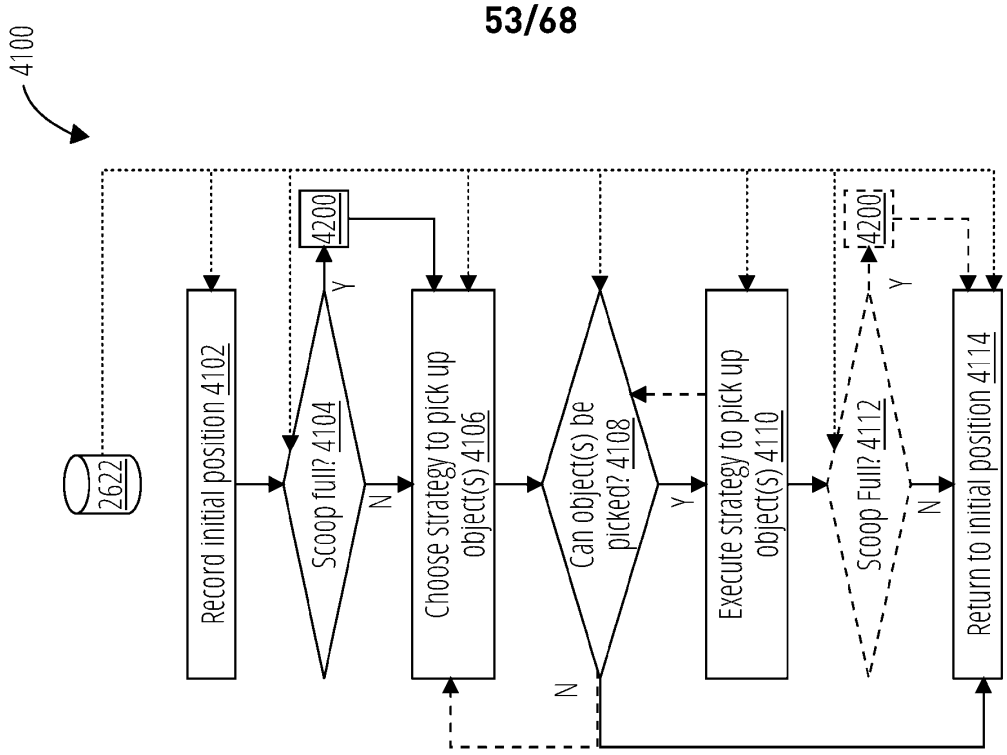

4100
2622
Record initial position 4102
Scoop full? 4104
Y
N
4200
Choose strategy to pick up object(s) 4106
Can object(s) be picked? 4108
Y
N
Execute strategy to pick up object(s) 4110
Scoop Full? 4112
Y
N
4200
Return to initial position 4114

FIG. 41

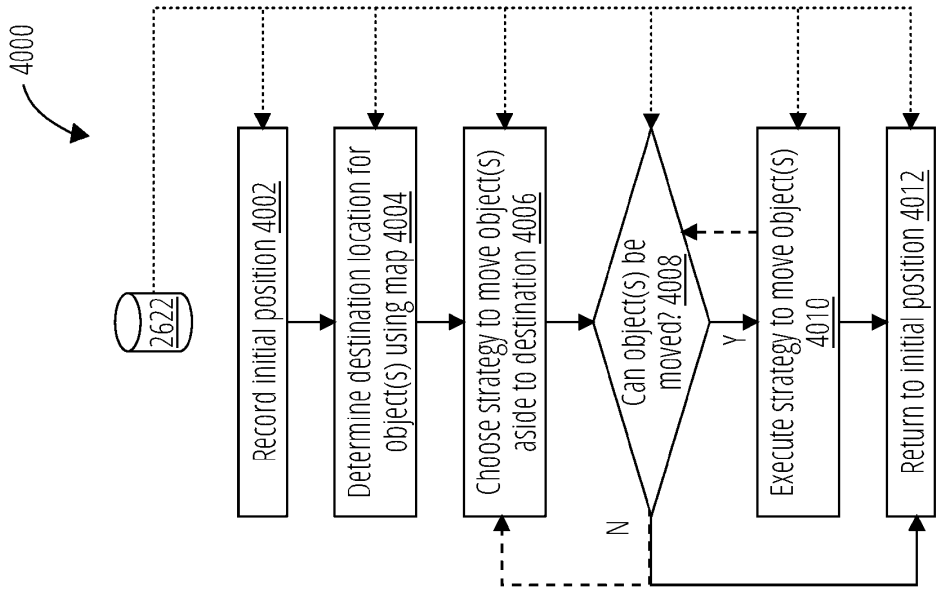

4000
2622
Record initial position 4002
Determine destination location for object(s) using map 4004
Choose strategy to move object(s) aside to destination 4006
Can object(s) be moved? 4008
Y
N
Execute strategy to move object(s) 4010
Return to initial position 4012

FIG. 40

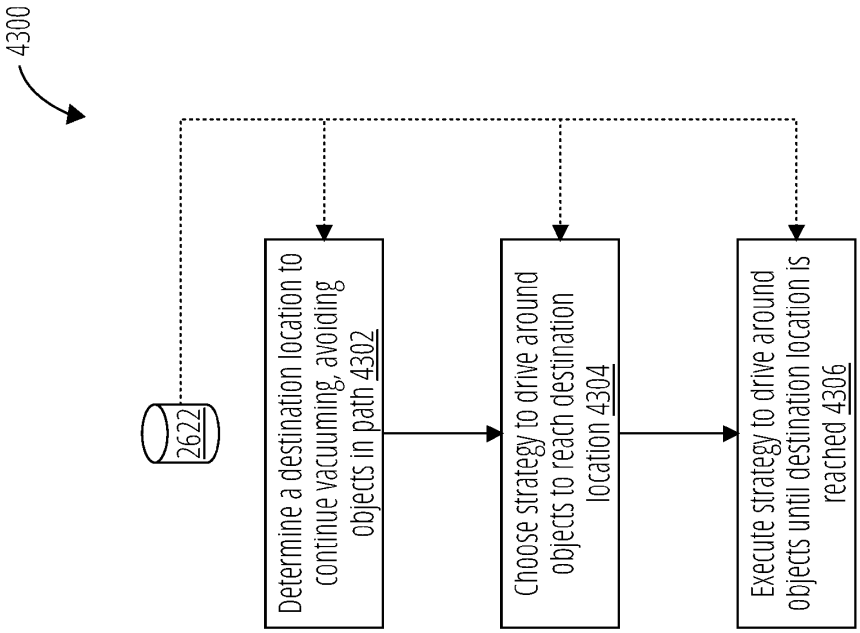

4300
2622
Determine a destination location to continue vacuuming, avoiding objects in path 4302
Choose strategy to drive around objects to reach destination location 4304
Execute strategy to drive around objects until destination location is reached 4306

FIG. 43

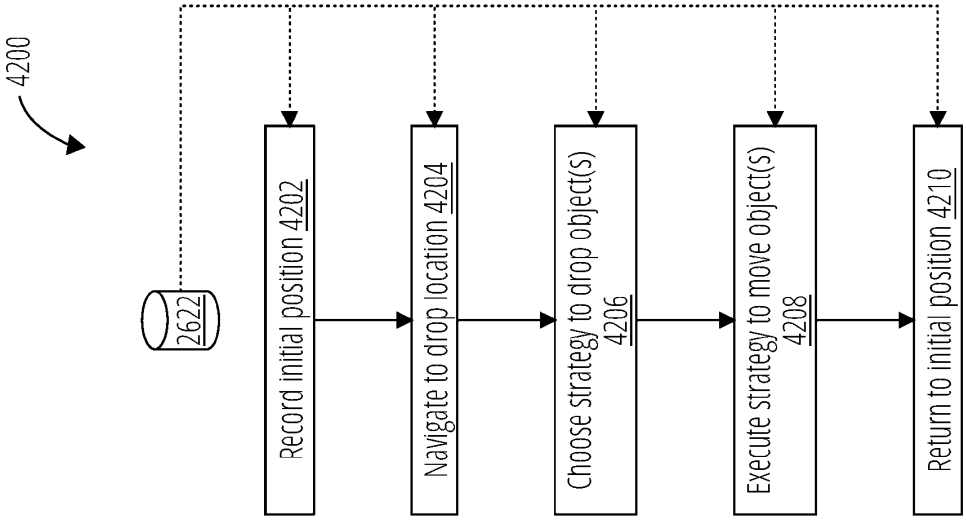

4200
2622
Record initial position 4202
Navigate to drop location 4204
Choose strategy to drop object(s) 4206
Execute strategy to move object(s) 4208
Return to initial position 4210

FIG. 42

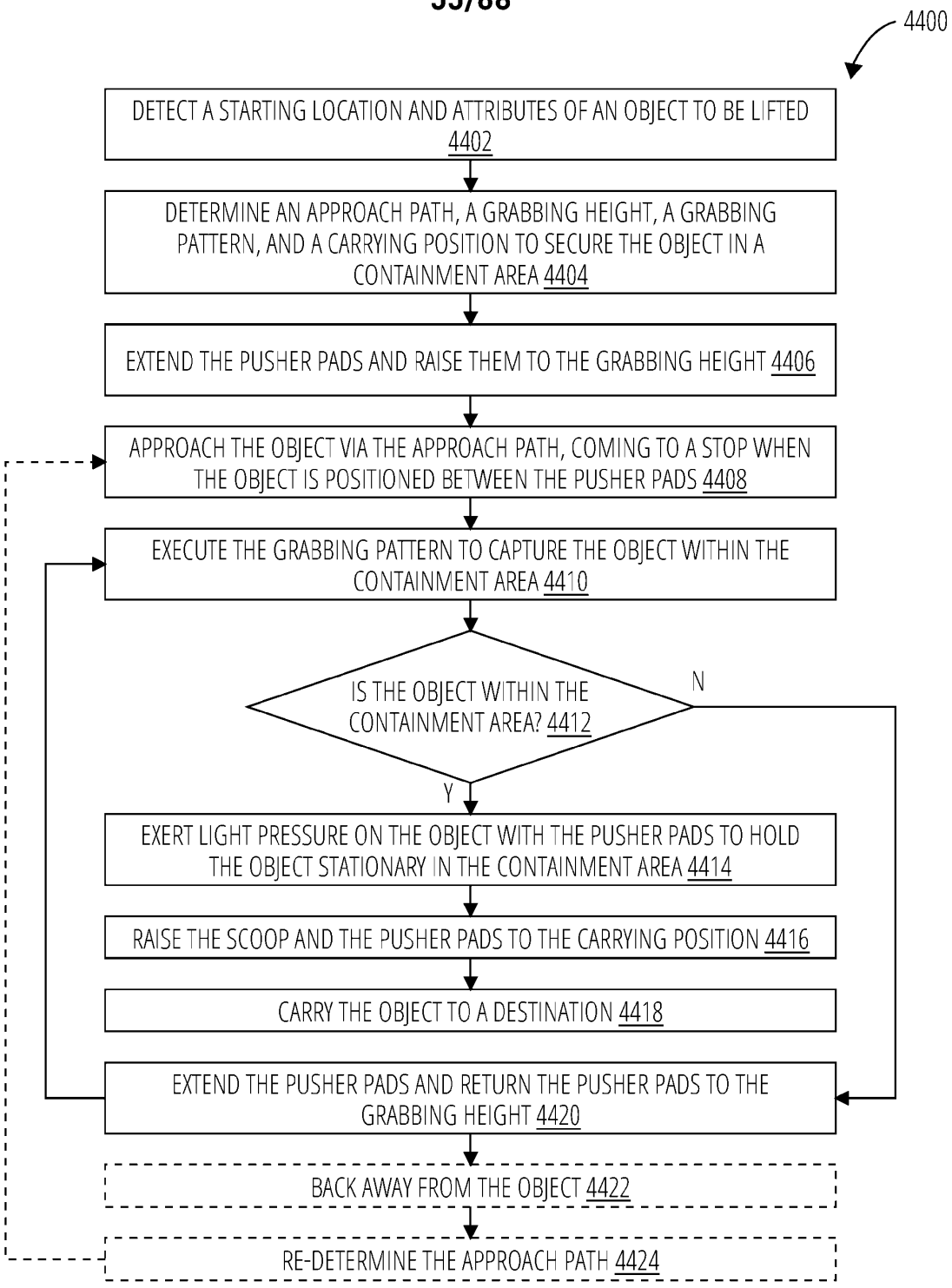

4400
DETECT A STARTING LOCATION AND ATTRIBUTES OF AN OBJECT TO BE LIFTED 4402
DETERMINE AN APPROACH PATH, A GRABBING HEIGHT, A GRABBING PATTERN, AND A CARRYING POSITION TO SECURE THE OBJECT IN A CONTAINMENT AREA 4404
EXTEND THE PUSHER PADS AND RAISE THEM TO THE GRABBING HEIGHT 4406
APPROACH THE OBJECT VIA THE APPROACH PATH, COMING TO A STOP WHEN THE OBJECT IS POSITIONED BETWEEN THE PUSHER PADS 4408
EXECUTE THE GRABBING PATTERN TO CAPTURE THE OBJECT WITHIN THE CONTAINMENT AREA 4410
IS THE OBJECT WITHIN THE CONTAINMENT AREA? 4412
N
Y
EXERT LIGHT PRESSURE ON THE OBJECT WITH THE PUSHER PADS TO HOLD THE OBJECT STATIONARY IN THE CONTAINMENT AREA 4414
RAISE THE SCOOP AND THE PUSHER PADS TO THE CARRYING POSITION 4416
CARRY THE OBJECT TO A DESTINATION 4418
EXTEND THE PUSHER PADS AND RETURN THE PUSHER PADS TO THE GRABBING HEIGHT 4420
BACK AWAY FROM THE OBJECT 4422
RE-DETERMINE THE APPROACH PATH 4424

FIG. 44

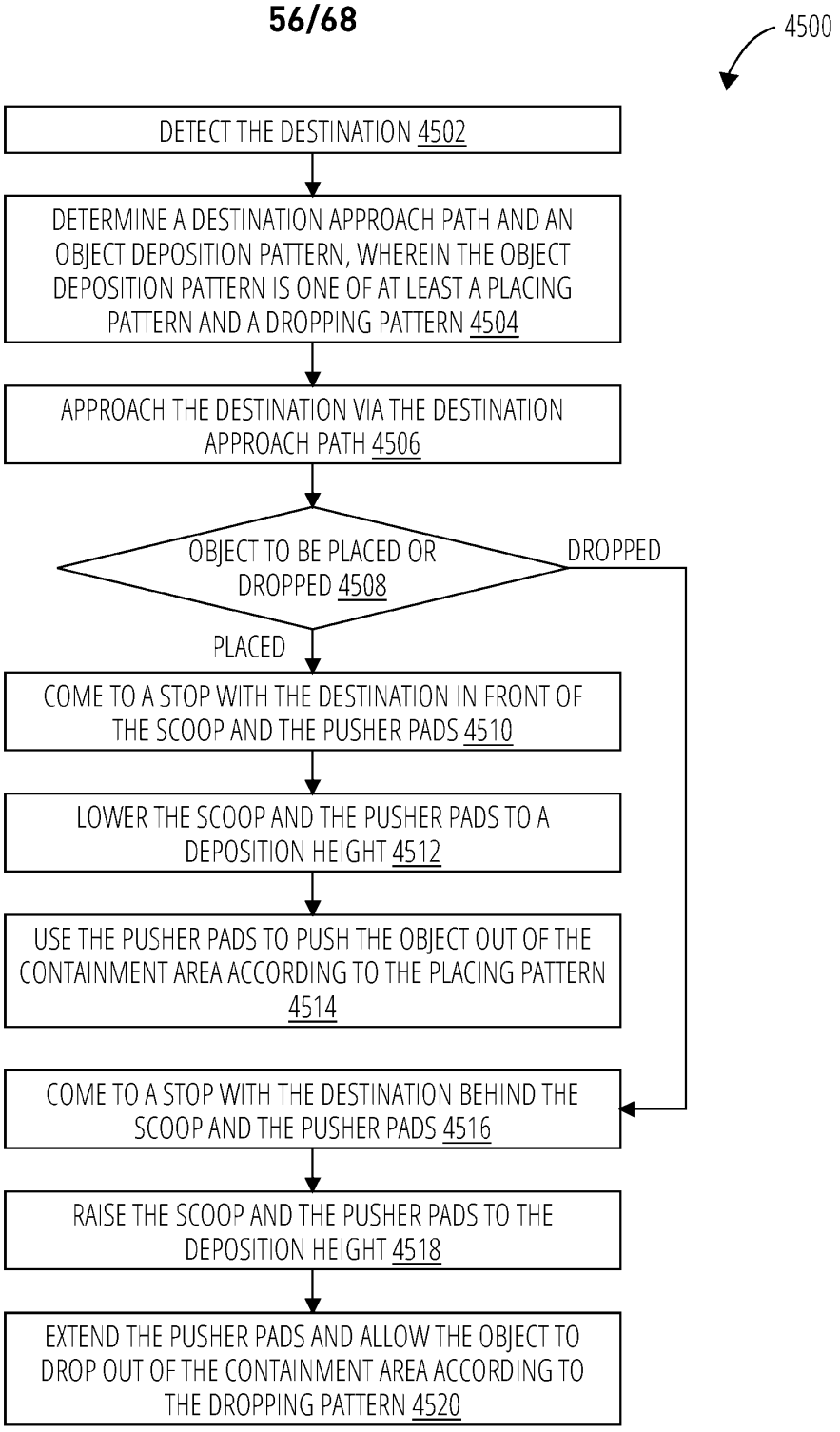

4500
DETECT THE DESTINATION 4502
DETERMINE A DESTINATION APPROACH PATH AND AN OBJECT DEPOSITION PATTERN, WHEREIN THE OBJECT DEPOSITION PATTERN IS ONE OF AT LEAST A PLACING PATTERN AND A DROPPING PATTERN 4504
APPROACH THE DESTINATION VIA THE DESTINATION APPROACH PATH 4506
OBJECT TO BE PLACED OR DROPPED 4508
DROPPED
PLACED
COME TO A STOP WITH THE DESTINATION IN FRONT OF THE SCOOP AND THE PUSHER PADS 4510
LOWER THE SCOOP AND THE PUSHER PADS TO A DEPOSITION HEIGHT 4512
USE THE PUSHER PADS TO PUSH THE OBJECT OUT OF THE CONTAINMENT AREA ACCORDING TO THE PLACING PATTERN 4514
COME TO A STOP WITH THE DESTINATION BEHIND THE SCOOP AND THE PUSHER PADS 4516
RAISE THE SCOOP AND THE PUSHER PADS TO THE DEPOSITION HEIGHT 4518
EXTEND THE PUSHER PADS AND ALLOW THE OBJECT TO DROP OUT OF THE CONTAINMENT AREA ACCORDING TO THE DROPPING PATTERN 4520

FIG. 45

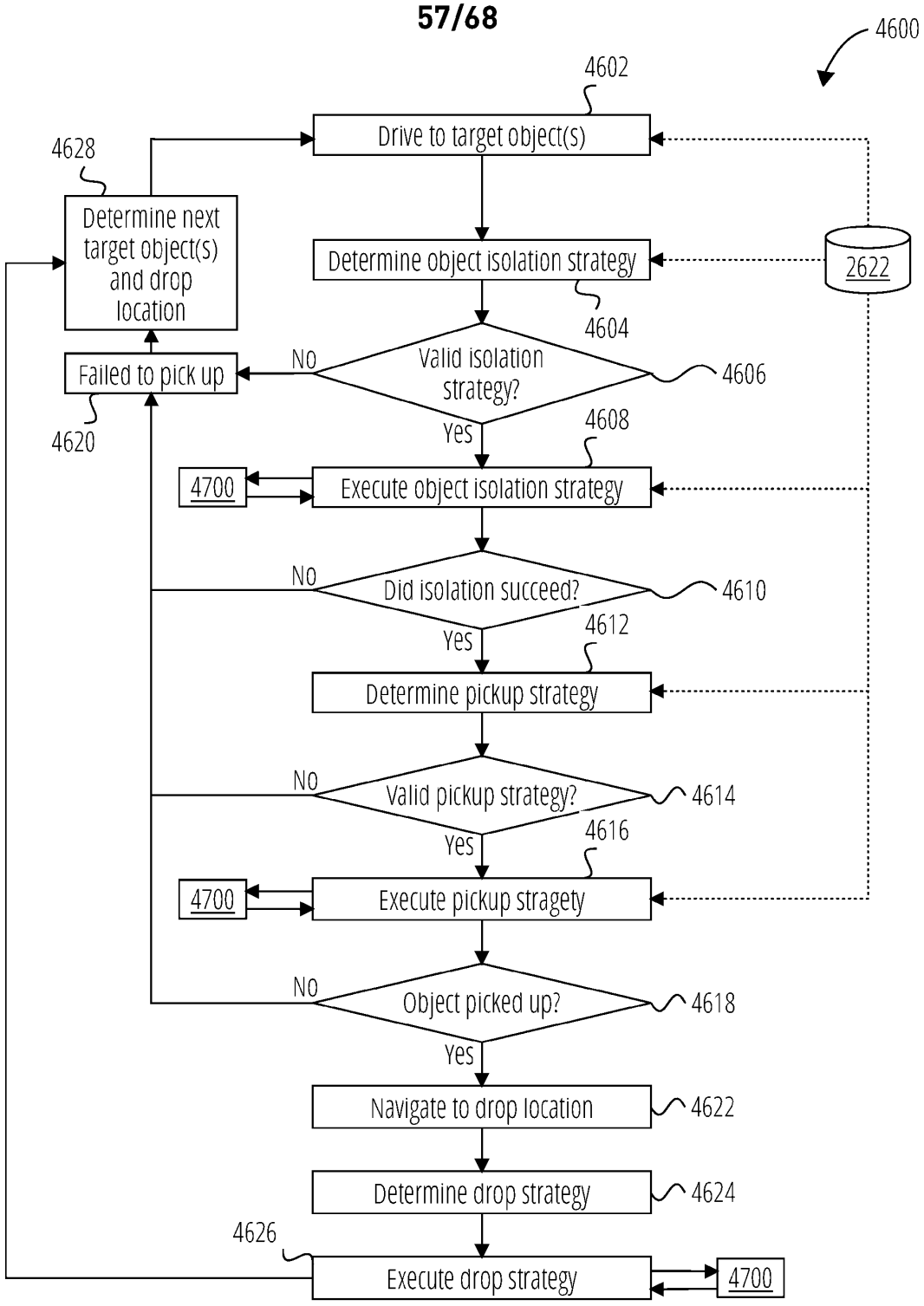

4600
4602
Drive to target object(s)
4628
Determine next target object(s) and drop location
Determine object isolation strategy
2622
4604
Valid isolation strategy?
4606
No
Failed to pick up
4620
Yes
4608
4700
Execute object isolation strategy
No
Did isolation succeed?
4610
Yes
4612
Determine pickup strategy
No
Valid pickup strategy?
4614
Yes
4616
4700
Execute pickup stragety
No
Object picked up?
4618
Yes
Navigate to drop location
4622
Determine drop strategy
4624
4626
Execute drop strategy
4700

FIG. 46

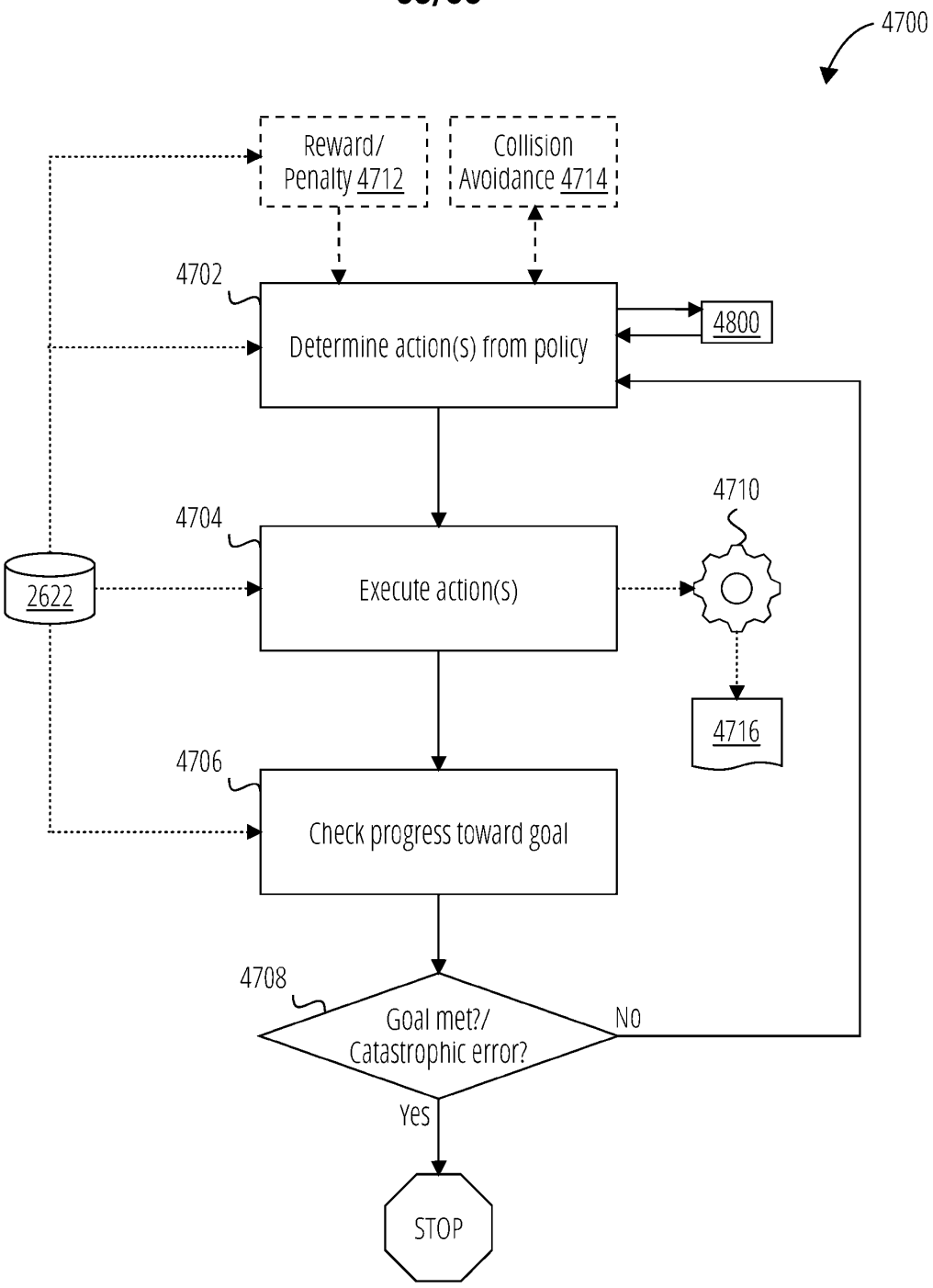

4700
Reward/ Penalty 4712
Collision Avoidance 4714
4702
Determine action(s) from policy
4800
4710
4704
Execute action(s)
2622
4716
4706
Check progress toward goal
4708
Goal met?/ Catastrophic error?
No
Yes
STOP

FIG. 47

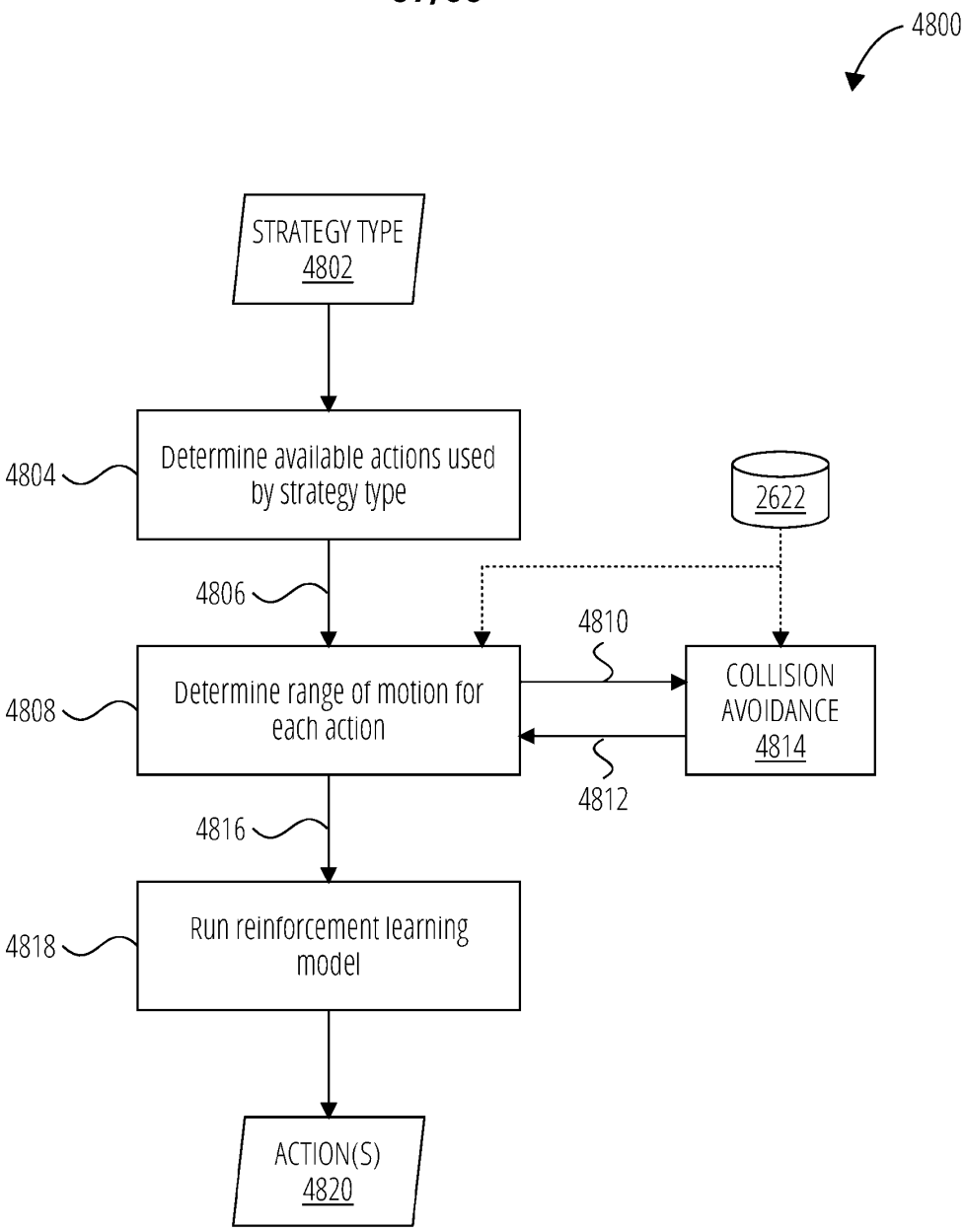

4800
STRATEGY TYPE
4802
4804
Determine available actions used by strategy type
2622
4806
4810
4808
Determine range of motion for each action
COLLISION AVOIDANCE
4814
4812
4816
4818
Run reinforcement learning model
ACTION(S)
4820

FIG. 48

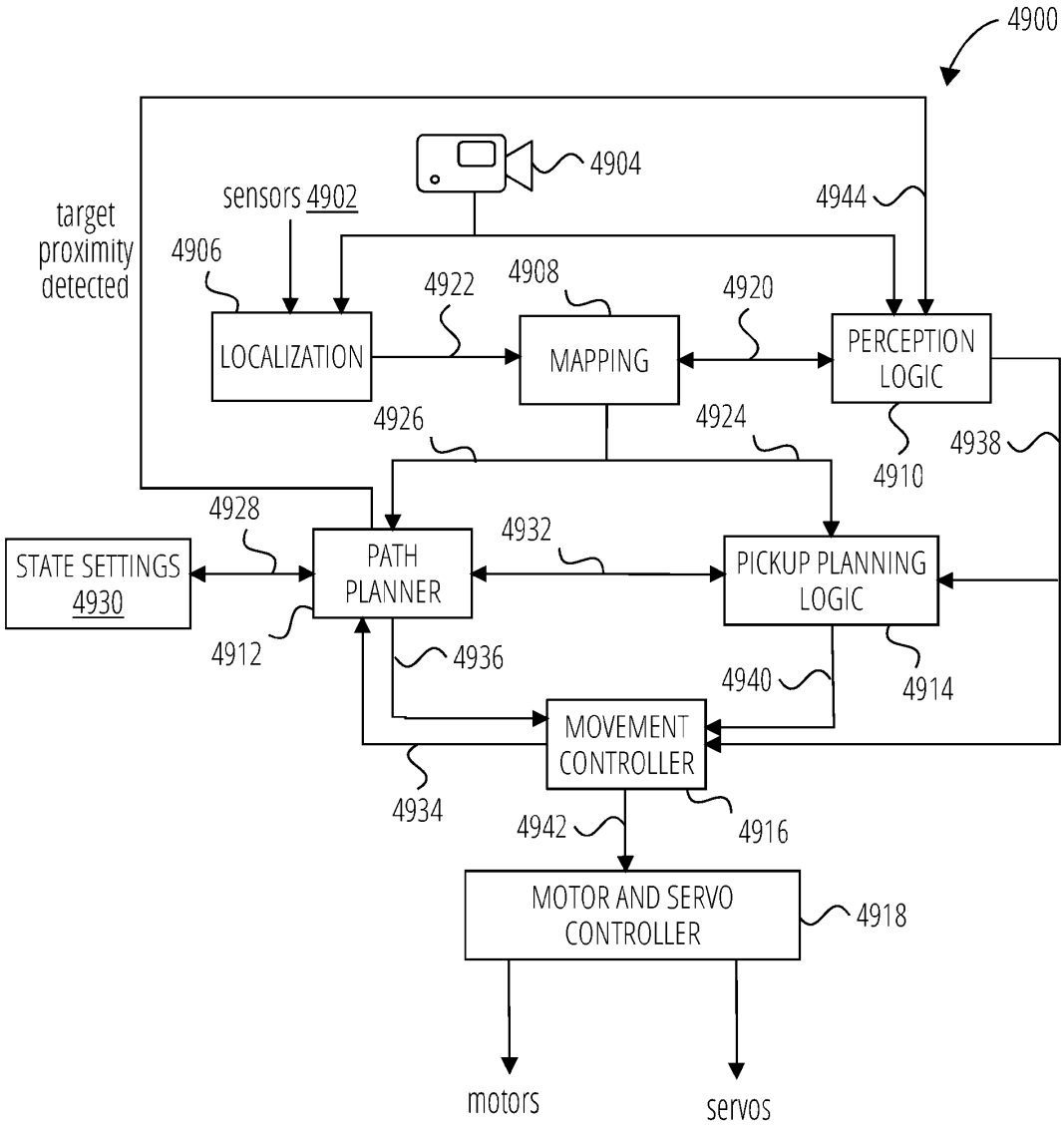

4900
4904
sensors 4902
4944
target proximity detected
4906
4922
4908
4920
LOCALIZATION
MAPPING
PERCEPTION LOGIC
4926
4924
4938
4910
4928
4932
STATE SETTINGS 4930
PATH PLANNER
PICKUP PLANNING LOGIC
4912
4936
4940
4914
MOVEMENT CONTROLLER
4934
4942
4916
MOTOR AND SERVO CONTROLLER
4918
motors
servos

FIG. 49

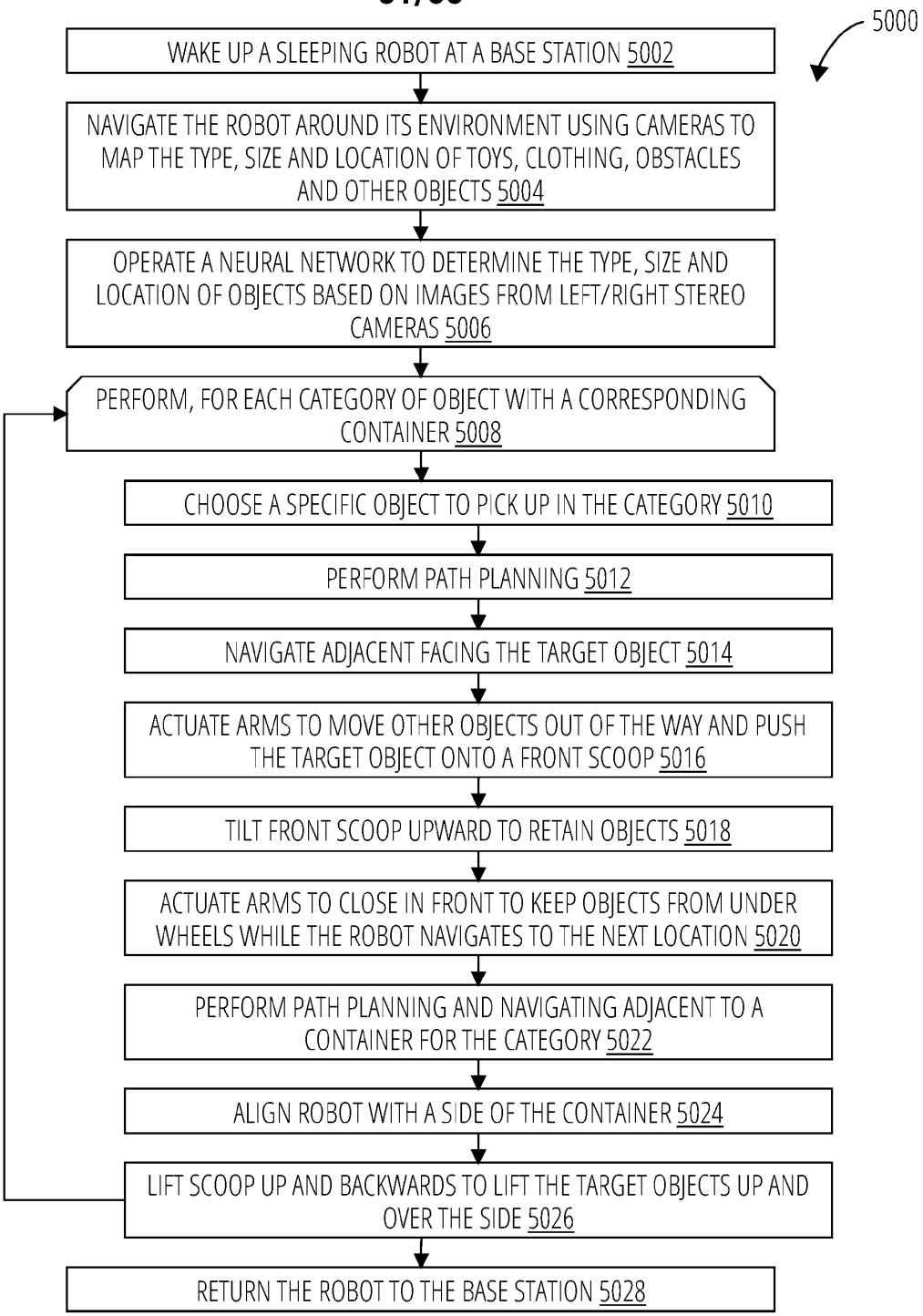

5000
WAKE UP A SLEEPING ROBOT AT A BASE STATION 5002
NAVIGATE THE ROBOT AROUND ITS ENVIRONMENT USING CAMERAS TO MAP THE TYPE, SIZE AND LOCATION OF TOYS, CLOTHING, OBSTACLES AND OTHER OBJECTS 5004
OPERATE A NEURAL NETWORK TO DETERMINE THE TYPE, SIZE AND LOCATION OF OBJECTS BASED ON IMAGES FROM LEFT/RIGHT STEREO CAMERAS 5006
PERFORM, FOR EACH CATEGORY OF OBJECT WITH A CORRESPONDING CONTAINER 5008
CHOOSE A SPECIFIC OBJECT TO PICK UP IN THE CATEGORY 5010
PERFORM PATH PLANNING 5012
NAVIGATE ADJACENT FACING THE TARGET OBJECT 5014
ACTUATE ARMS TO MOVE OTHER OBJECTS OUT OF THE WAY AND PUSH THE TARGET OBJECT ONTO A FRONT SCOOP 5016
TILT FRONT SCOOP UPWARD TO RETAIN OBJECTS 5018
ACTUATE ARMS TO CLOSE IN FRONT TO KEEP OBJECTS FROM UNDER WHEELS WHILE THE ROBOT NAVIGATES TO THE NEXT LOCATION 5020
PERFORM PATH PLANNING AND NAVIGATING ADJACENT TO A CONTAINER FOR THE CATEGORY 5022
ALIGN ROBOT WITH A SIDE OF THE CONTAINER 5024
LIFT SCOOP UP AND BACKWARDS TO LIFT THE TARGET OBJECTS UP AND OVER THE SIDE 5026
RETURN THE ROBOT TO THE BASE STATION 5028

FIG. 50

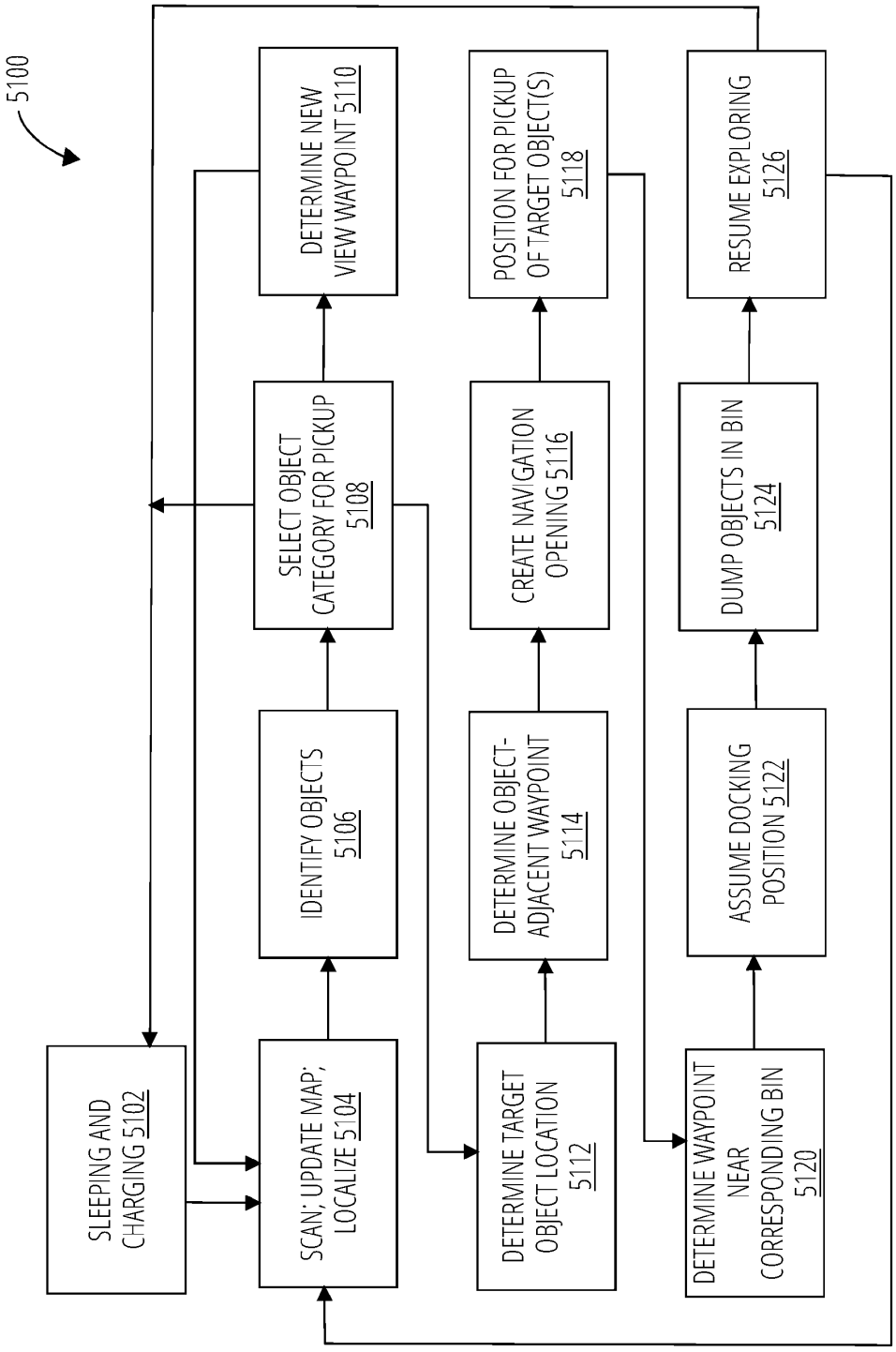

5100
SLEEPING AND CHARGING 5102
SCAN; UPDATE MAP; LOCALIZE 5104
IDENTIFY OBJECTS 5106
SELECT OBJECT CATEGORY FOR PICKUP 5108
DETERMINE NEW VIEW WAYPOINT 5110
DETERMINE TARGET OBJECT LOCATION 5112
DETERMINE OBJECT-ADJACENT WAYPOINT 5114
CREATE NAVIGATION OPENING 5116
POSITION FOR PICKUP OF TARGET OBJECT(S) 5118
DETERMINE WAYPOINT NEAR CORRESPONDING BIN 5120
ASSUME DOCKING POSITION 5122
DUMP OBJECTS IN BIN 5124
RESUME EXPLORING 5126

FIG. 51

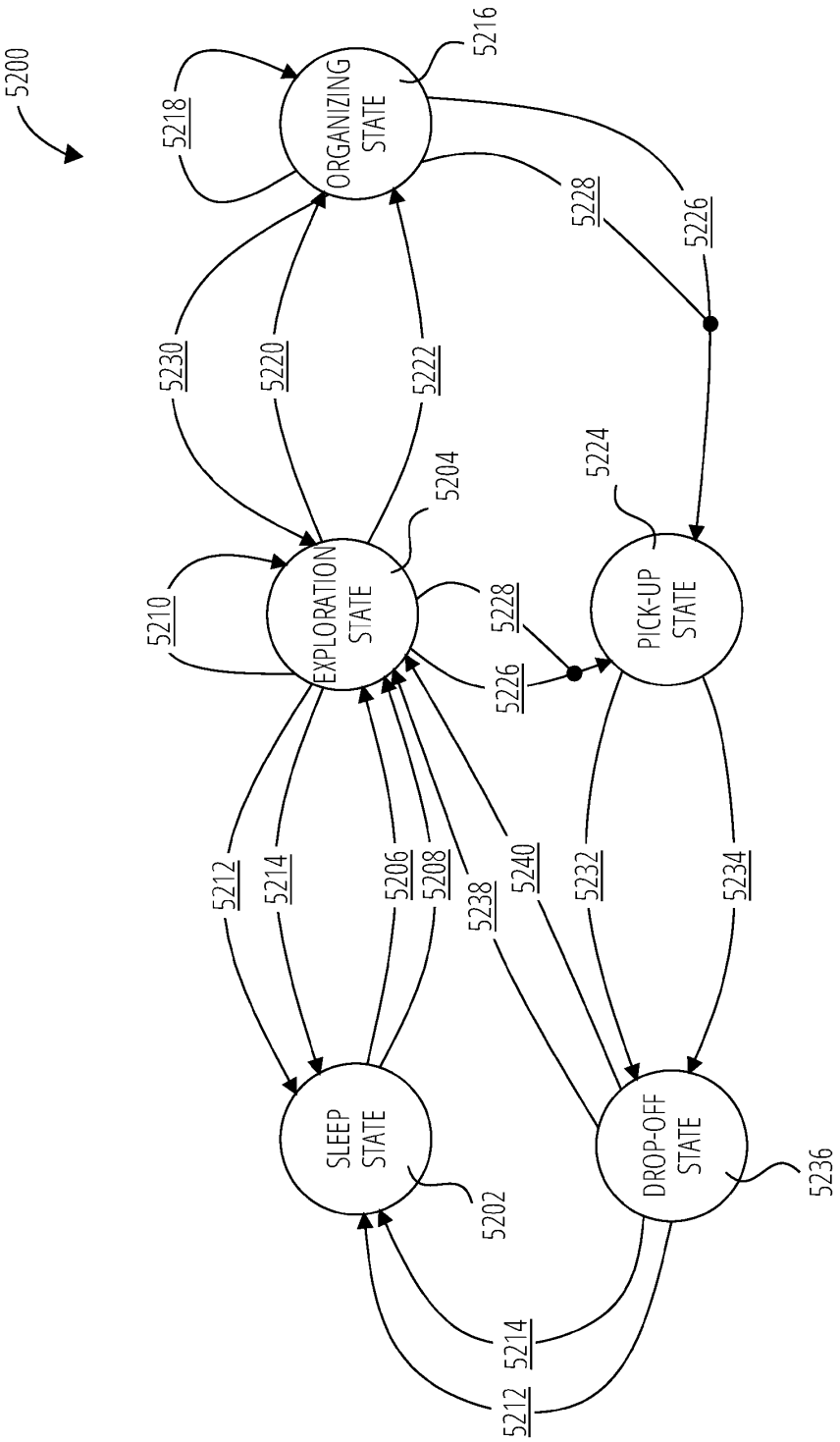

5200
ORGANIZING STATE
5216
5218
5228
5226
5230
5220
5222
EXPLORATION STATE
5204
5210
5228
5226
PICK-UP STATE
5224
5212
5214
5206
5208
5238
5240
5232
5234
SLEEP STATE
5202
DROP-OFF STATE
5236
5214
5212

FIG. 52

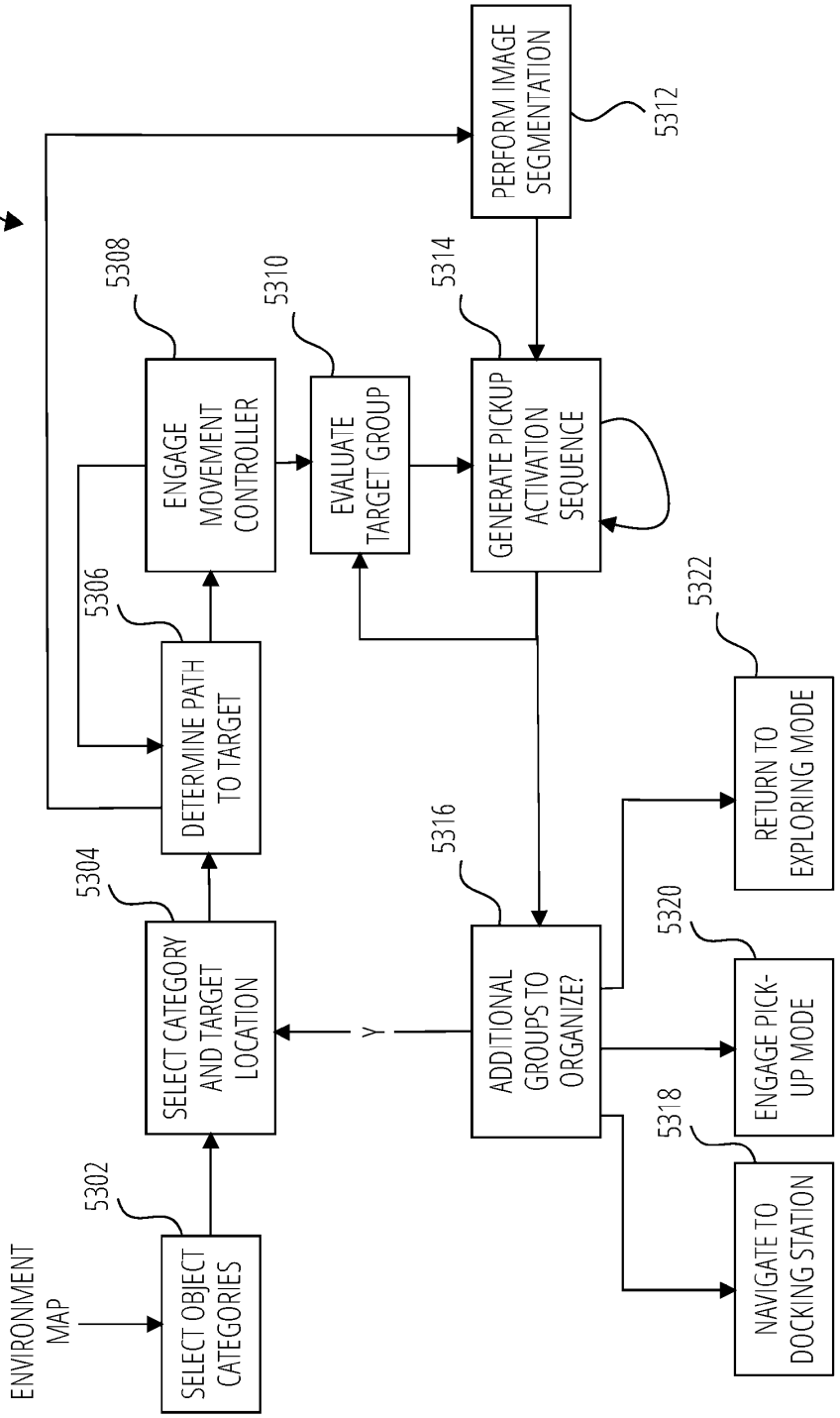

5300
PERFORM IMAGE SEGMENTATION
5312
5308
ENGAGE MOVEMENT CONTROLLER
5310
EVALUATE TARGET GROUP
5314
GENERATE PICKUP ACTIVATION SEQUENCE
5306
DETERMINE PATH TO TARGET
5322
RETURN TO EXPLORING MODE
5304
SELECT CATEGORY AND TARGET LOCATION
5316
ADDITIONAL GROUPS TO ORGANIZE?
Y
5320
ENGAGE PICK-UP MODE
5318
NAVIGATE TO DOCKING STATION
5302
SELECT OBJECT CATEGORIES
ENVIRONMENT MAP

FIG. 53

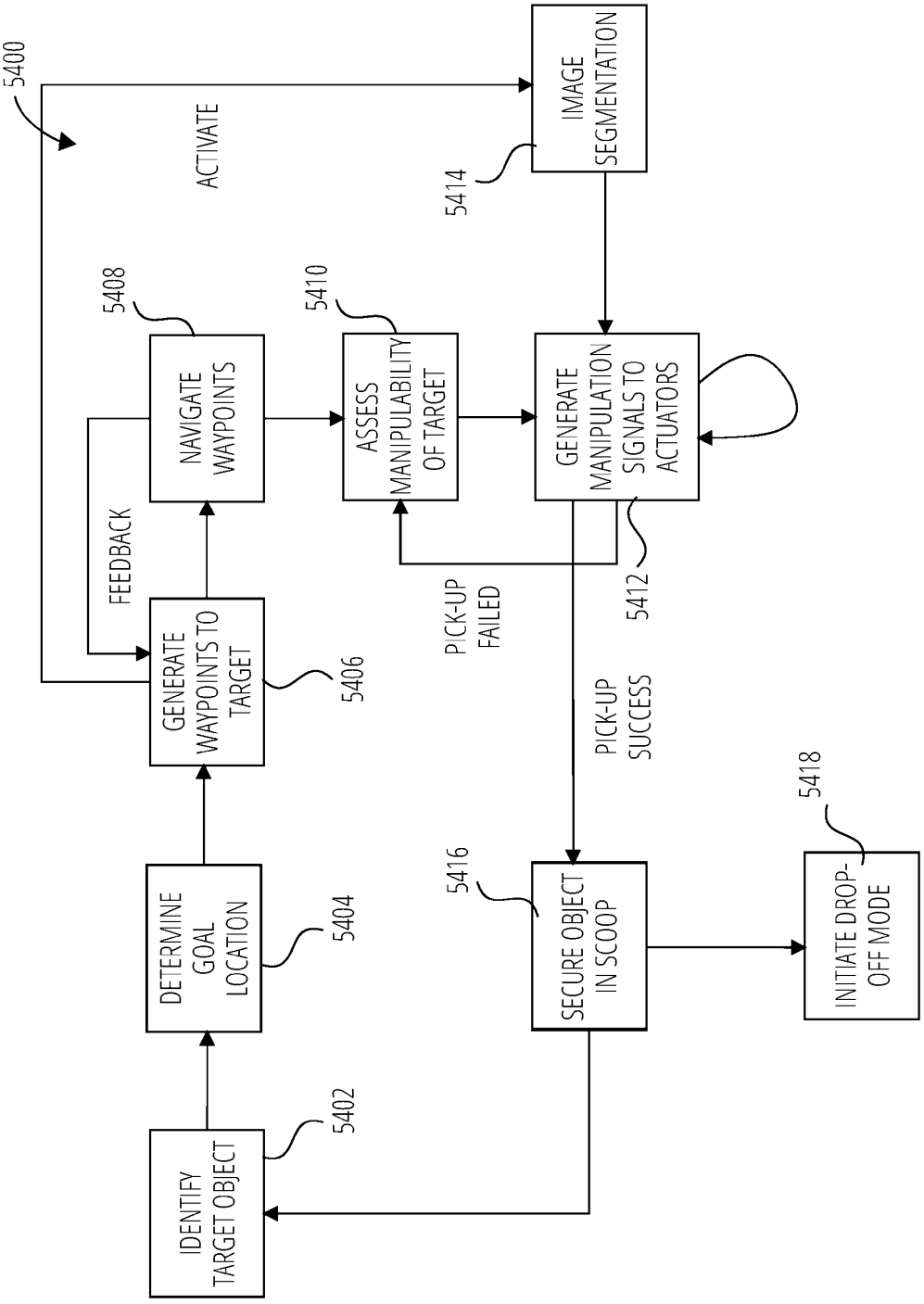

5400
ACTIVATE
IMAGE SEGMENTATION
5414
5408
NAVIGATE WAYPOINTS
5410
ASSESS MANIPULABILITY OF TARGET
GENERATE MANIPULATION SIGNALS TO ACTUATORS
FEEDBACK
GENERATE WAYPOINTS TO TARGET
5406
PICK-UP FAILED
5412
PICK-UP SUCCESS
5418
5416
DETERMINE GOAL LOCATION
5404
SECURE OBJECT IN SCOOP
INITIATE DROP-OFF MODE
IDENTIFY TARGET OBJECT
5402

FIG. 54

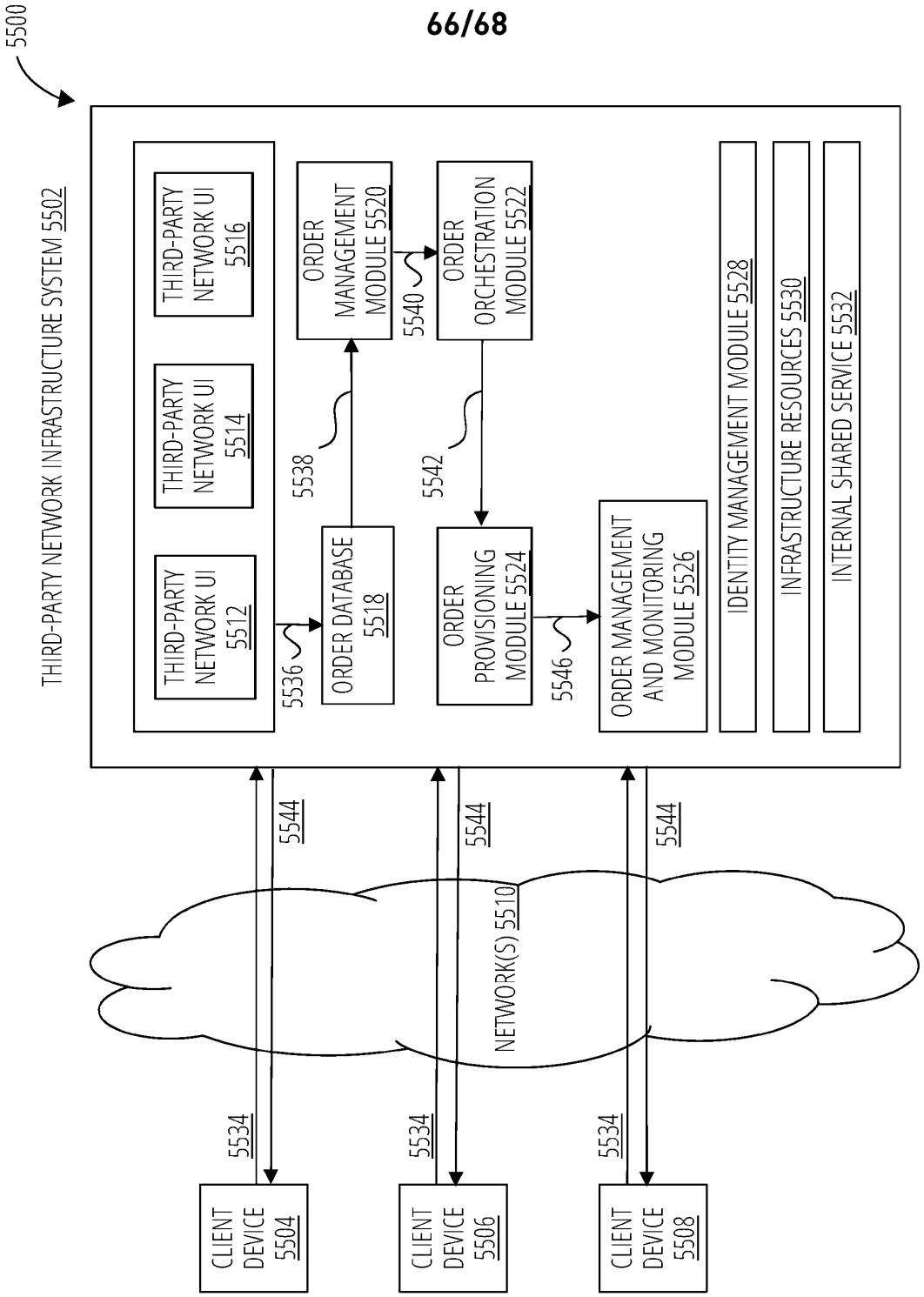

5500
THIRD-PARTY NETWORK INFRASTRUCTURE SYSTEM 5502
THIRD-PARTY NETWORK UI 5512
THIRD-PARTY NETWORK UI 5514
THIRD-PARTY NETWORK UI 5516
ORDER DATABASE 5518
ORDER MANAGEMENT MODULE 5520
ORDER ORCHESTRATION MODULE 5522
ORDER PROVISIONING MODULE 5524
ORDER MANAGEMENT AND MONITORING MODULE 5526
IDENTITY MANAGEMENT MODULE 5528
INFRASTRUCTURE RESOURCES 5530
INTERNAL SHARED SERVICE 5532
5536
5538
5540
5542
5546
5544
5544
5544
NETWORK(S) 5510
5534
5534
5534
CLIENT DEVICE 5504
CLIENT DEVICE 5506
CLIENT DEVICE 5508

FIG. 55

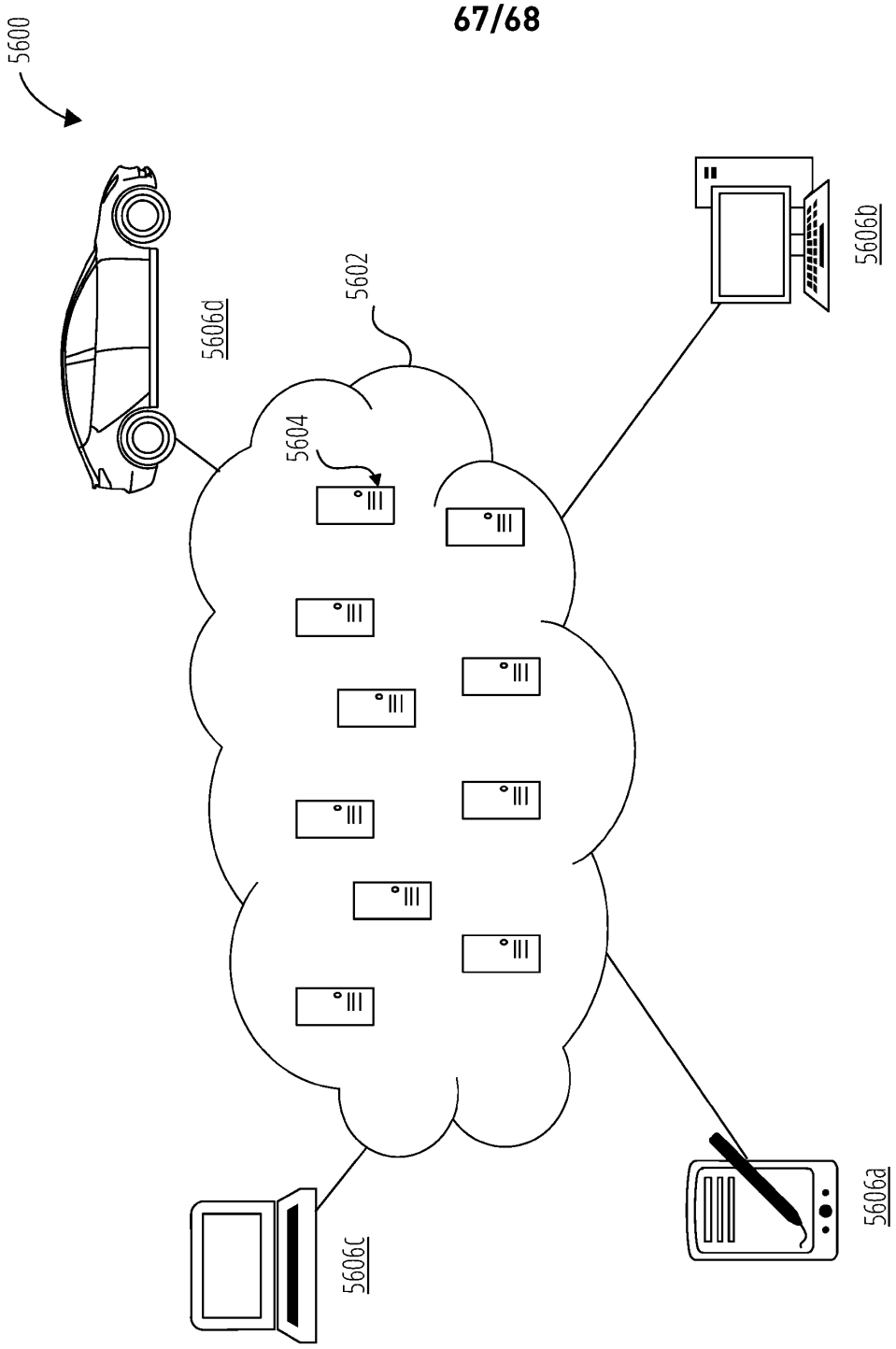


FIG. 56

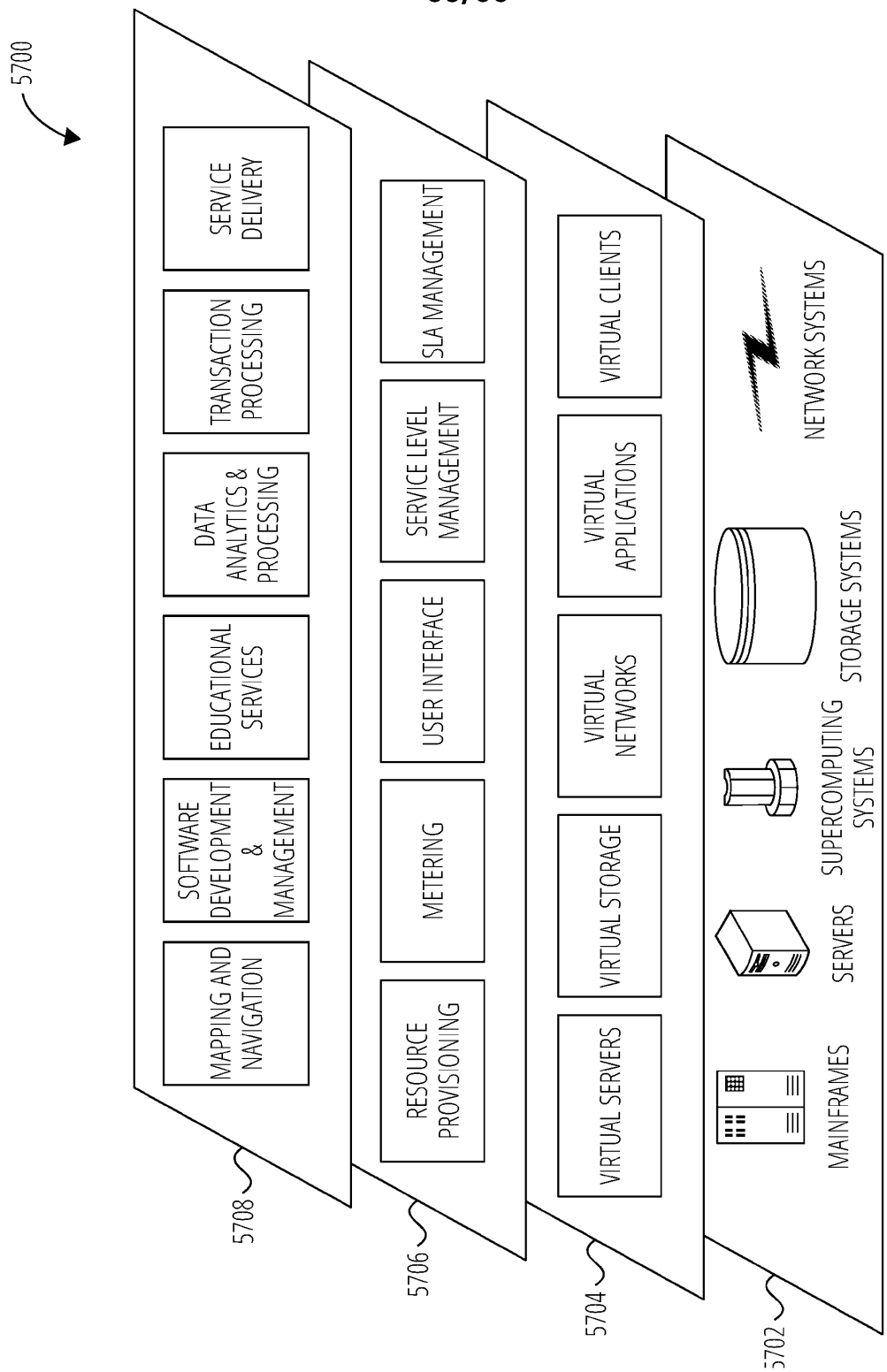

5700
MAPPING AND NAVIGATION
SOFTWARE DEVELOPMENT & MANAGEMENT
EDUCATIONAL SERVICES
DATA ANALYTICS & PROCESSING
TRANSACTION PROCESSING
SERVICE DELIVERY
RESOURCE PROVISIONING
METERING
USER INTERFACE
SERVICE LEVEL MANAGEMENT
SLA MANAGEMENT
VIRTUAL SERVERS
VIRTUAL STORAGE
VIRTUAL NETWORKS
VIRTUAL APPLICATIONS
VIRTUAL CLIENTS
MAINFRAMES
SERVERS
SUPERCOMPUTING SYSTEMS
STORAGE SYSTEMS
NETWORK SYSTEMS
5708
5706
5704
5702

FIG. 57