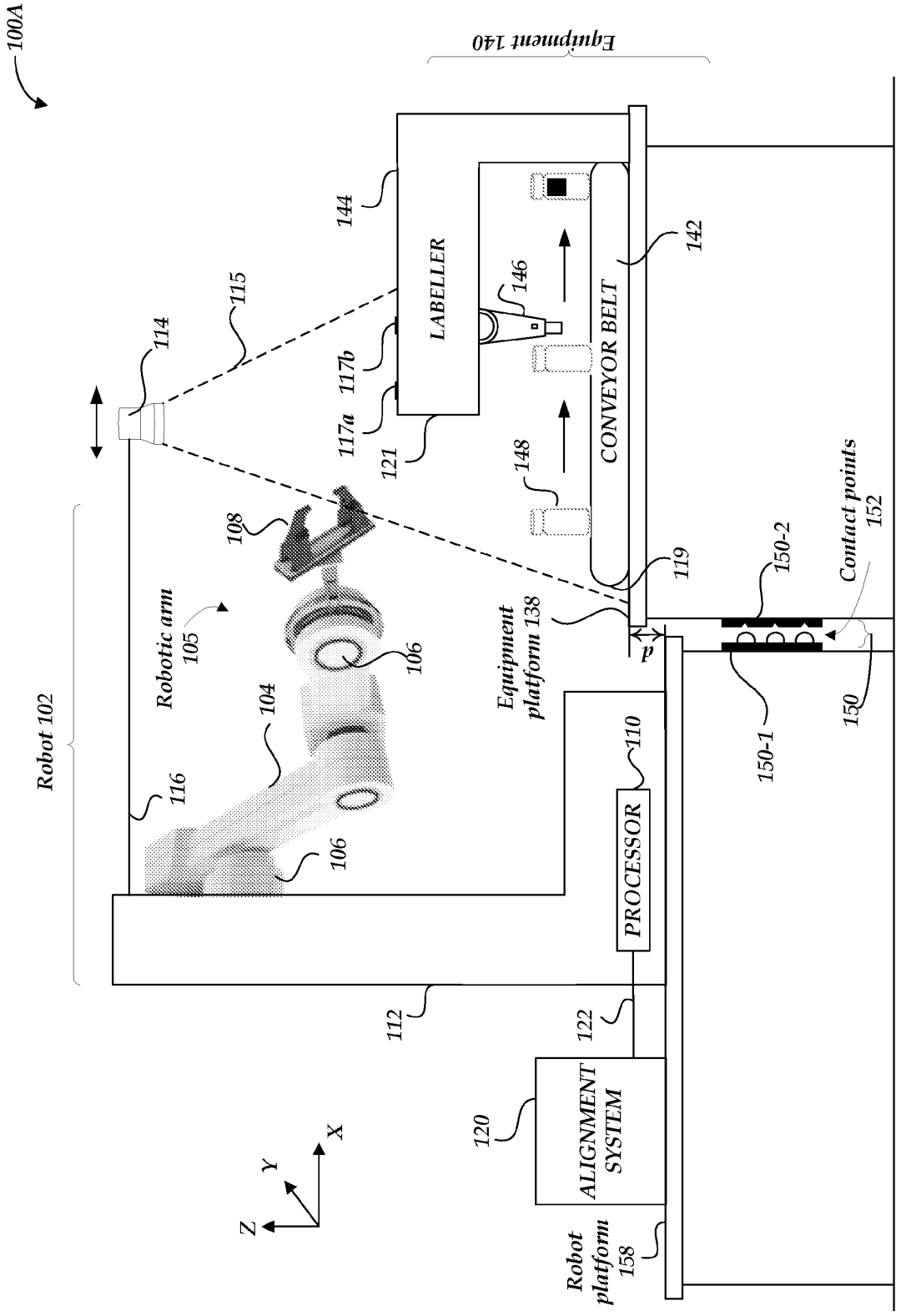

100A
Equipment 140
144
LABELLER
146
142
CONVEYOR BELT
115
114
117b
117a
121
148
108
Robotic arm
105
Robot 102
104
106
116
106
Equipment platform 138
119
150-2
Contact points
152
p
PROCESSOR
110
150-1
150
112
122
120
ALIGNMENT SYSTEM
Robot platform
158
Z
Y
X

FIG. 1A

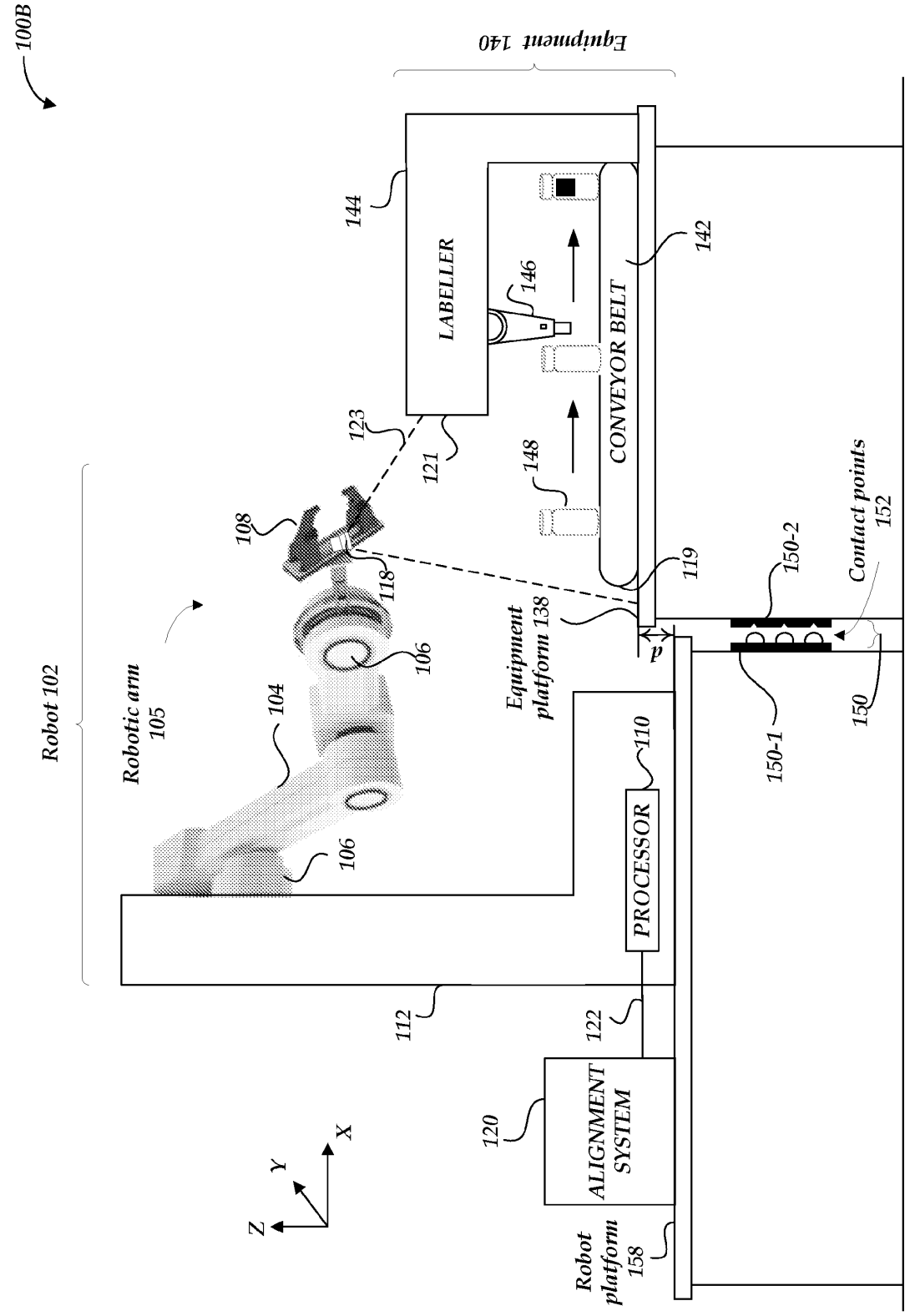

100B
Equipment 140
144
LABELLER
146
142
CONVEYOR BELT
123
121
148
108
118
119
150-2
Contact points
152
Robot 102
Robotic arm
105
104
106
Equipment platform 138
p
106
PROCESSOR
110
150-1
150
112
122
120
ALIGNMENT SYSTEM
Robot platform
158
Z
Y
X

FIG. 1B

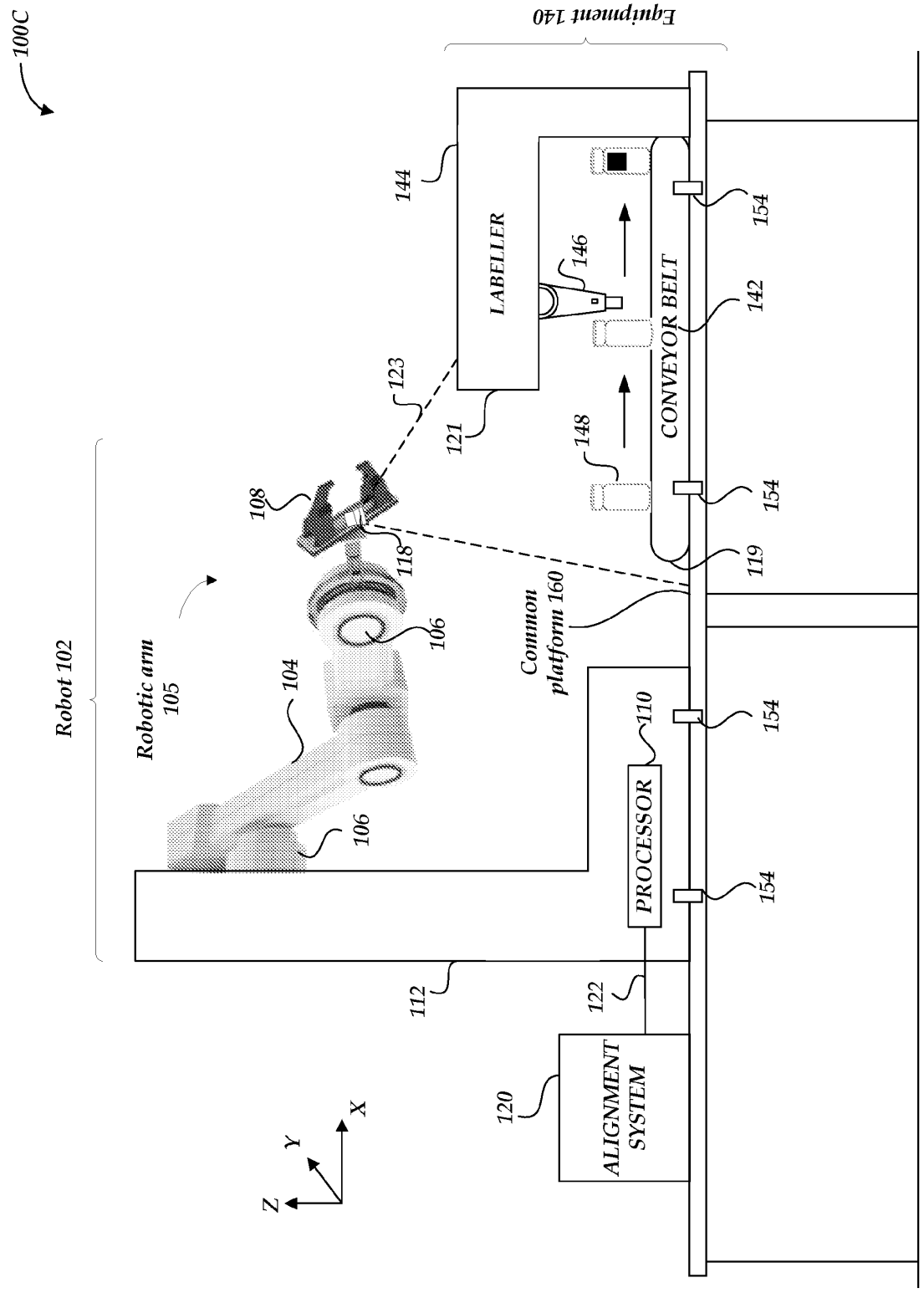

100C
Equipment 140
144
LABELLER
146
CONVEYOR BELT
142
154
123
121
148
108
118
119
Common platform 160
Robot 102
Robotic arm 105
104
106
106
110
PROCESSOR
112
122
120
ALIGNMENT SYSTEM
X
Y
Z

FIG. 1C

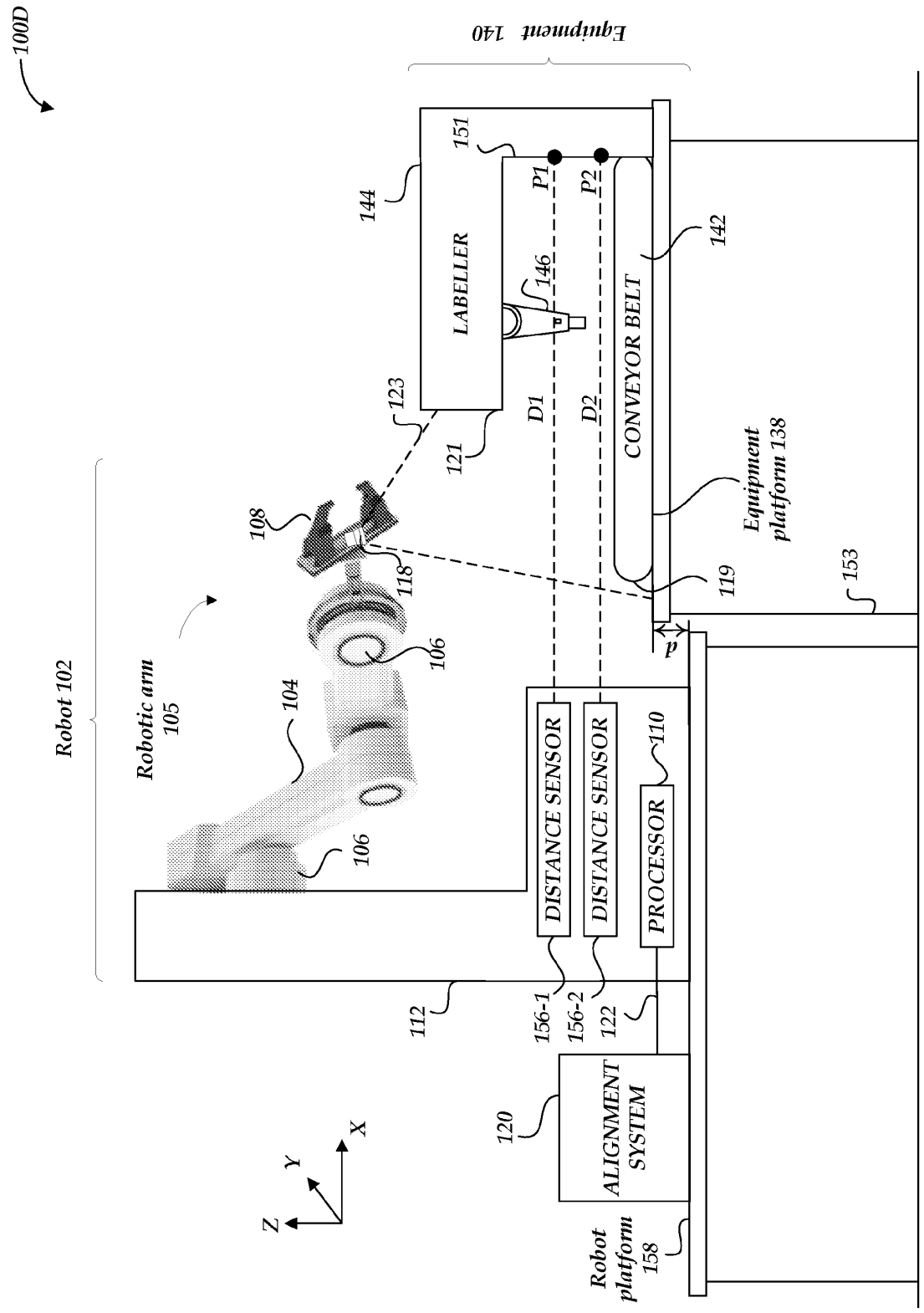

100D
Equipment 140
144
151
P1
P2
142
LABELLER
146
CONVEYOR BELT
123
121
D1
D2
Equipment platform 138
108
118
119
153
Robot 102
Robotic arm 105
106
104
106
p
DISTANCE SENSOR
DISTANCE SENSOR
PROCESSOR
110
112
156-1
156-2
122
120
ALIGNMENT SYSTEM
Robot platform 158
Y
X
Z

FIG. 1D

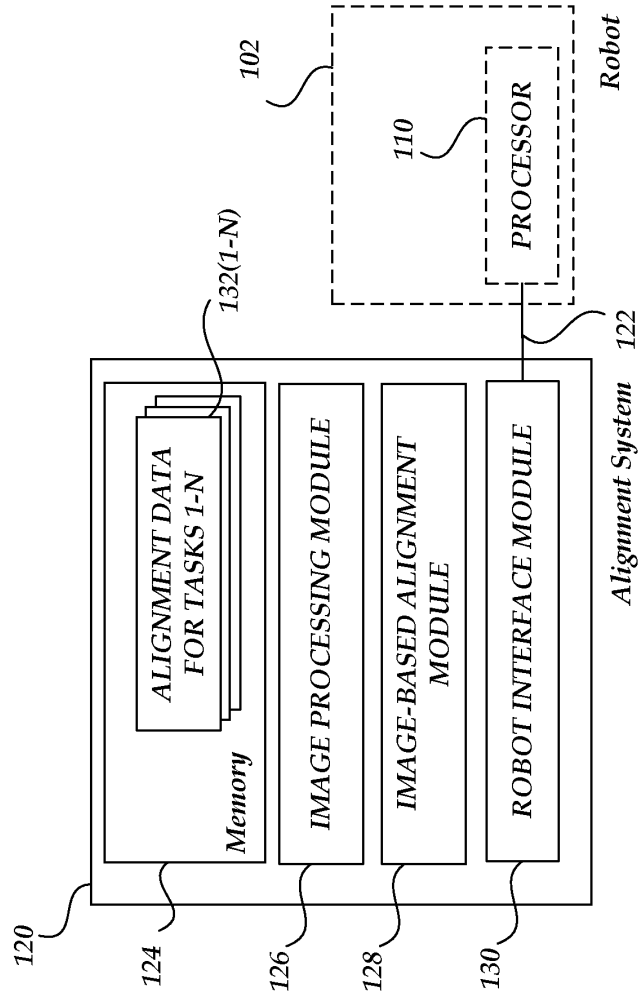

102
Robot
110
PROCESSOR
132(1-N)
122
ALIGNMENT DATA FOR TASKS 1-N
Memory
IMAGE PROCESSING MODULE
IMAGE-BASED ALIGNMENT MODULE
ROBOT INTERFACE MODULE
Alignment System
120
124
126
128
130

FIG. 1E

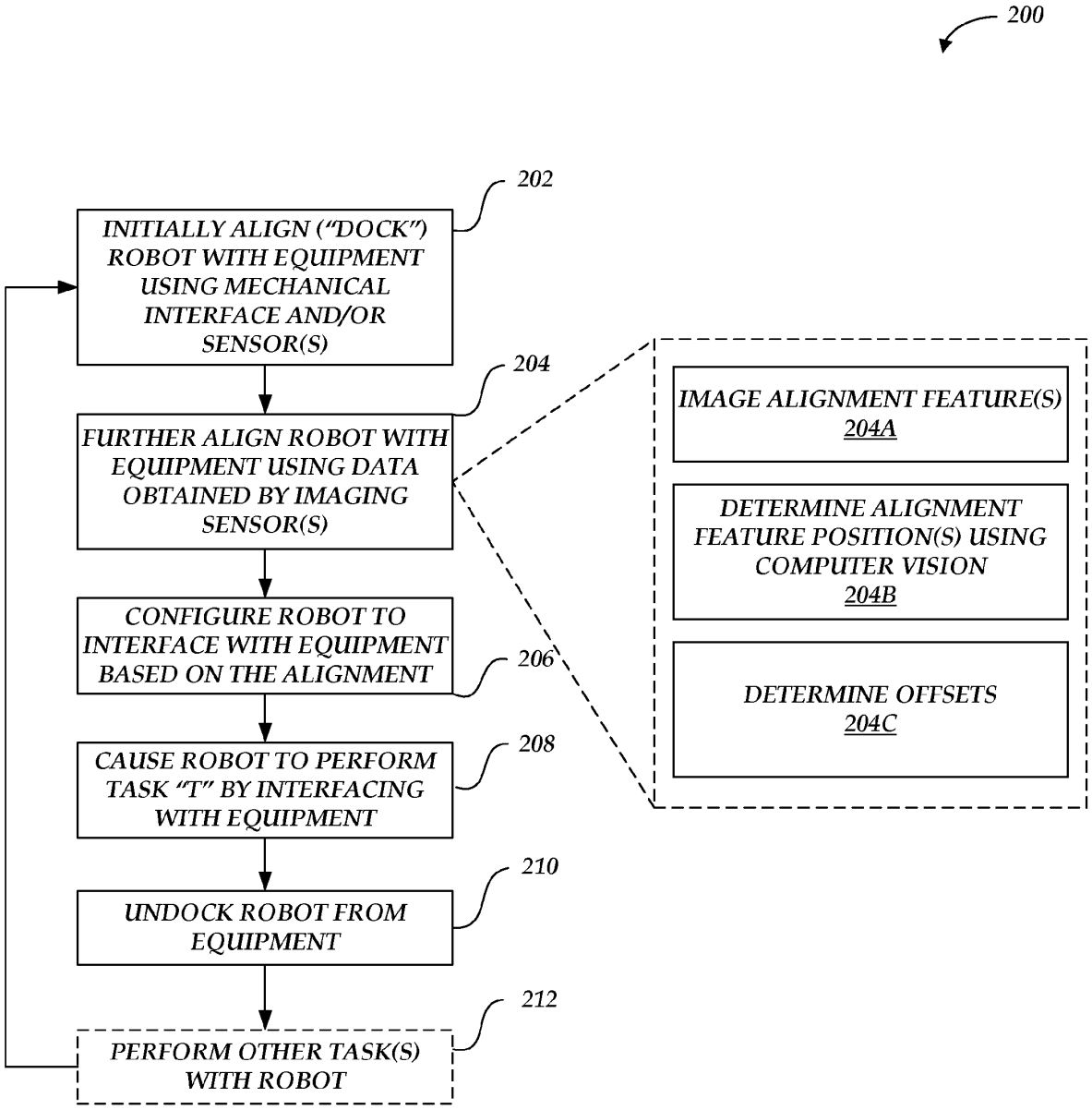

200
202
INITIALLY ALIGN ("DOCK") ROBOT WITH EQUIPMENT USING MECHANICAL INTERFACE AND/OR SENSOR(S)
204
FURTHER ALIGN ROBOT WITH EQUIPMENT USING DATA OBTAINED BY IMAGING SENSOR(S)
IMAGE ALIGNMENT FEATURE(S) 204A
DETERMINE ALIGNMENT FEATURE POSITION(S) USING COMPUTER VISION 204B
DETERMINE OFFSETS 204C
206
CONFIGURE ROBOT TO INTERFACE WITH EQUIPMENT BASED ON THE ALIGNMENT
208
CAUSE ROBOT TO PERFORM TASK "T" BY INTERFACING WITH EQUIPMENT
210
UNDOCK ROBOT FROM EQUIPMENT
212
PERFORM OTHER TASK(S) WITH ROBOT

FIG. 2

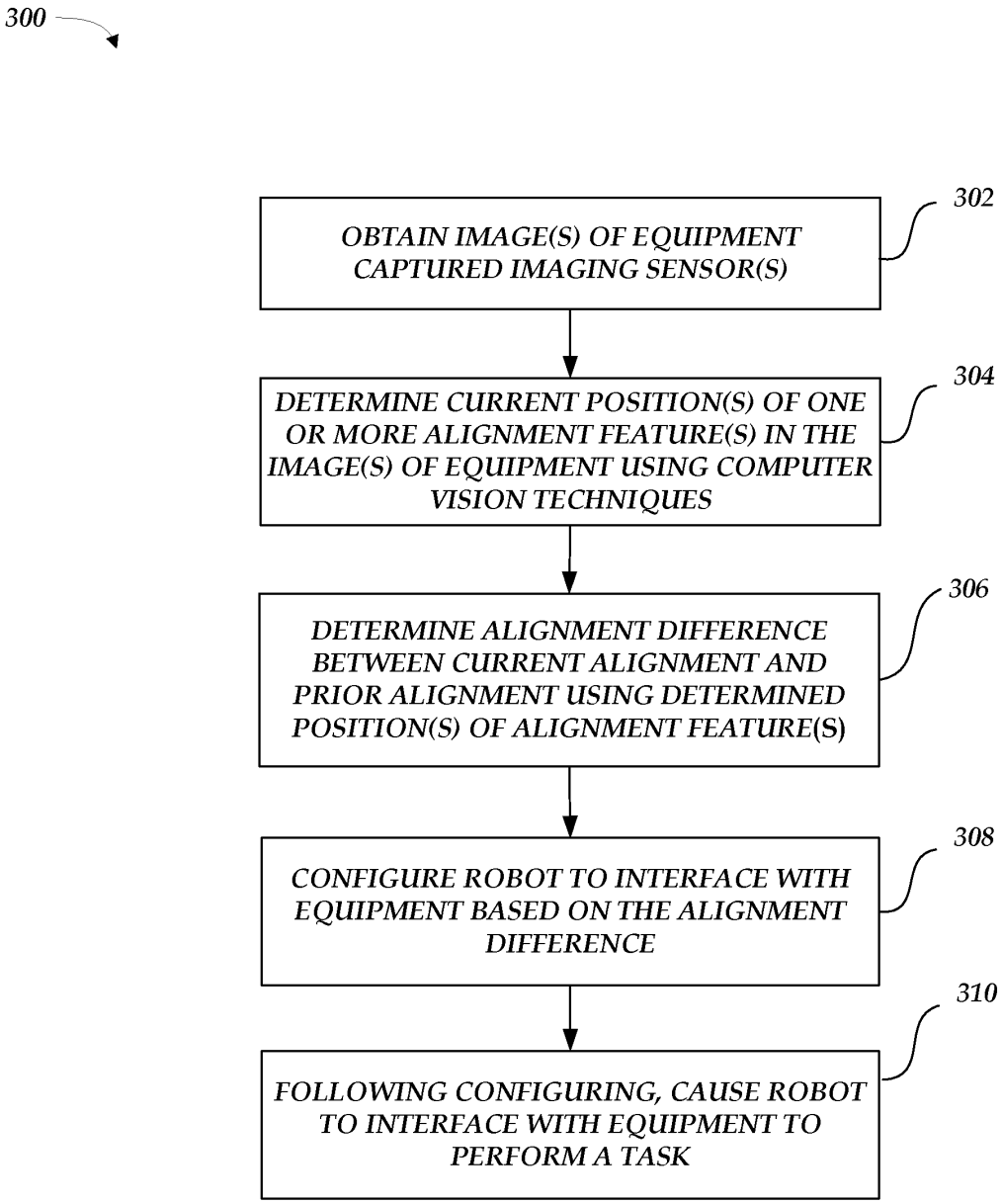

300
OBTAIN IMAGE(S) OF EQUIPMENT CAPTURED IMAGING SENSOR(S)
302
DETERMINE CURRENT POSITION(S) OF ONE OR MORE ALIGNMENT FEATURE(S) IN THE IMAGE(S) OF EQUIPMENT USING COMPUTER VISION TECHNIQUES
304
DETERMINE ALIGNMENT DIFFERENCE BETWEEN CURRENT ALIGNMENT AND PRIOR ALIGNMENT USING DETERMINED POSITION(S) OF ALIGNMENT FEATURE(S)
306
CONFIGURE ROBOT TO INTERFACE WITH EQUIPMENT BASED ON THE ALIGNMENT DIFFERENCE
308
FOLLOWING CONFIGURING, CAUSE ROBOT TO INTERFACE WITH EQUIPMENT TO PERFORM A TASK
310

FIG. 3

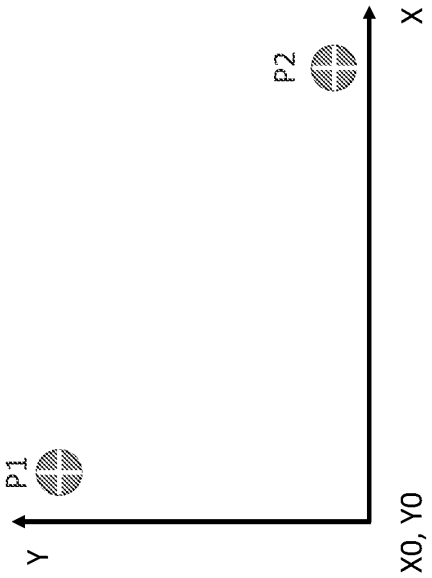


FIG. 4B

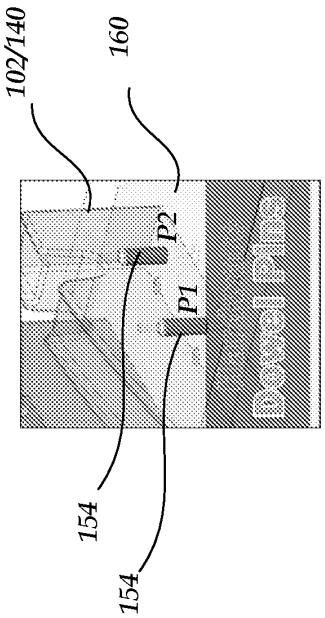


FIG. 4A

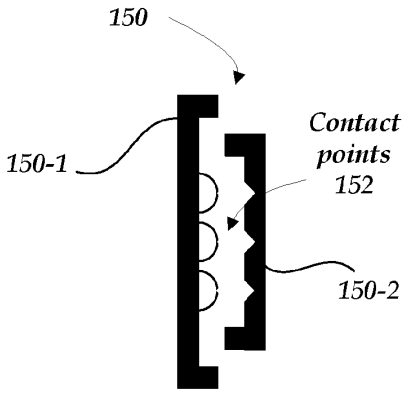


FIG. 5A

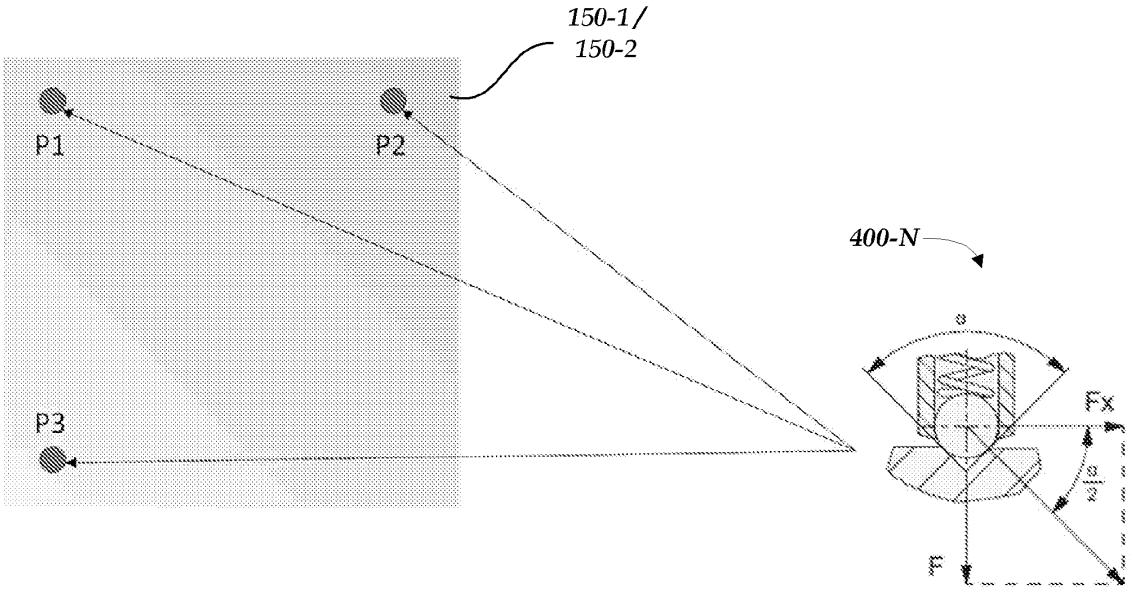


FIG. 5B

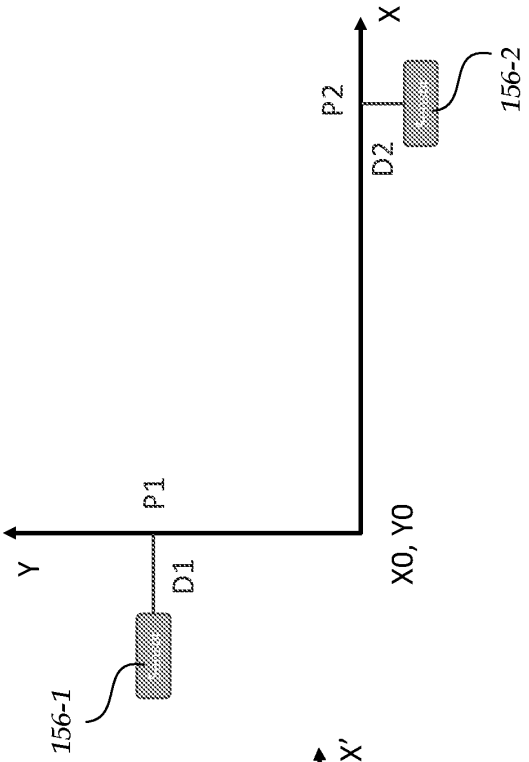


FIG. 6B

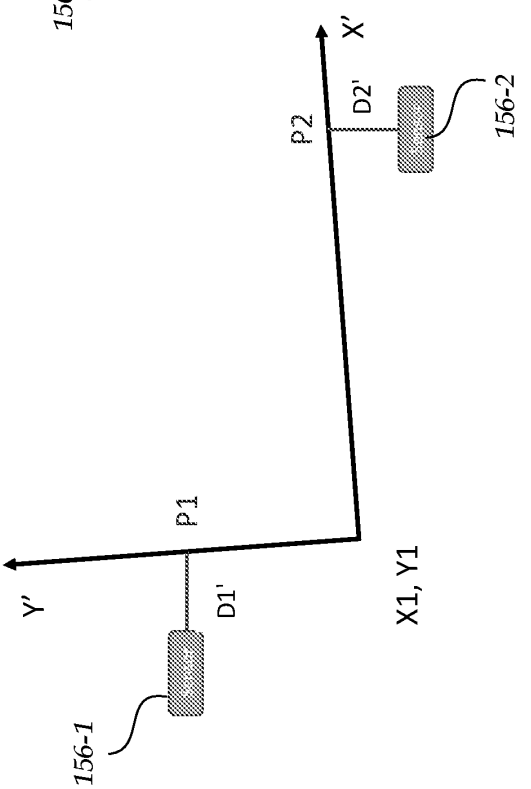


FIG. 6A

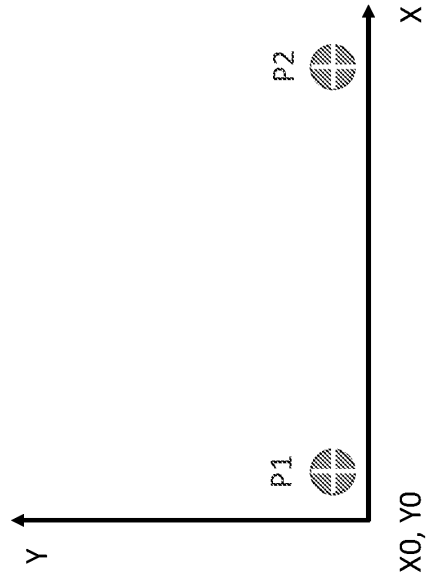


FIG. 7B

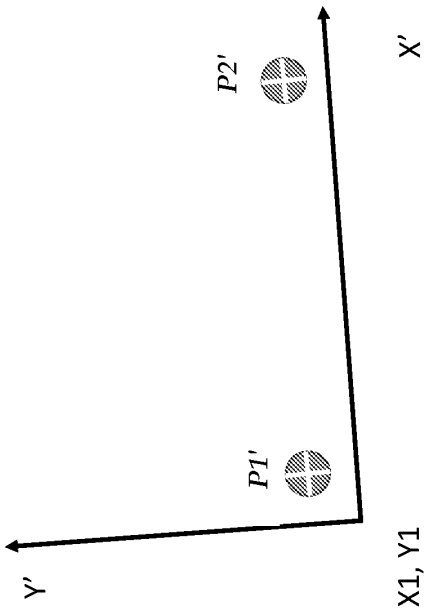


FIG. 7A

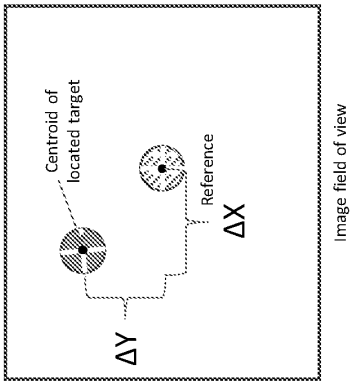

Centroid of
located target
Reference
ΔX
ΔY
Image field of view

FIG. 8B

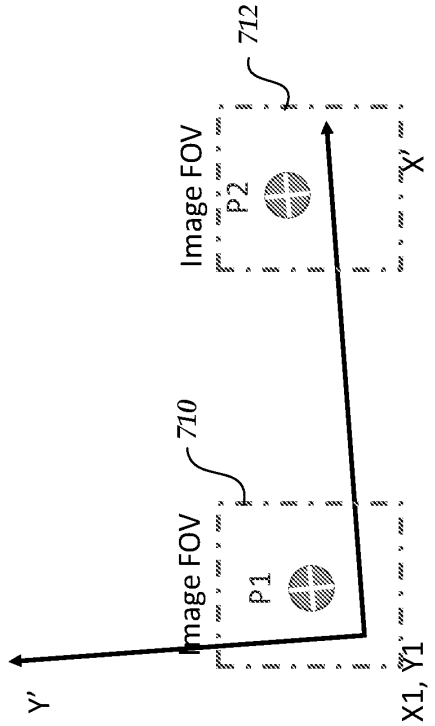

Y'
X1, Y1
X'
Image FOV
710
P1
Image FOV
712
P2

FIG. 8A

$$\text{Offset} \equiv P_1{}' - P_1 \equiv x_{P_1'}, y_{P_1'}$$

$$\theta \equiv \tan^{-1}\left(\frac{y_{P_2'} - y_{P_1'}}{x_{P_2'} - x_{P_1'}}\right)$$

$$\begin{pmatrix} x' \\ y' \end{pmatrix} \equiv \begin{pmatrix} x_{P1'} & 0 \\ 0 & y_{P1'} \end{pmatrix} + \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$$

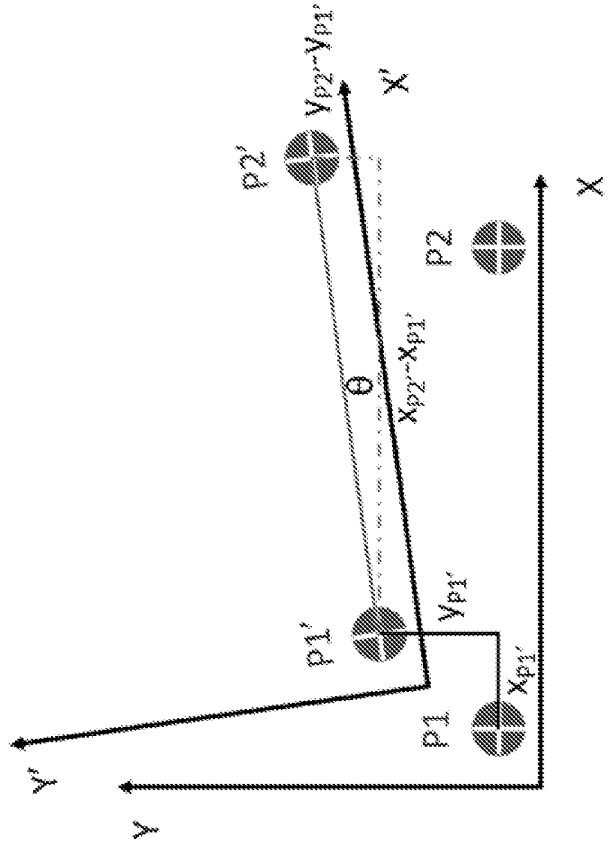


FIG. 8C

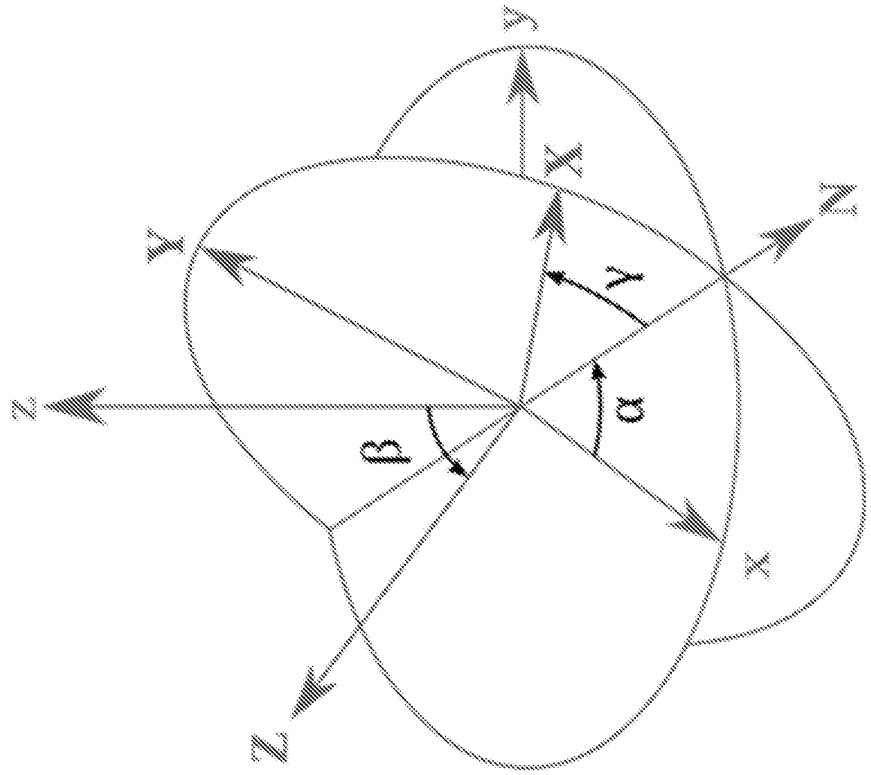


FIG. 9A

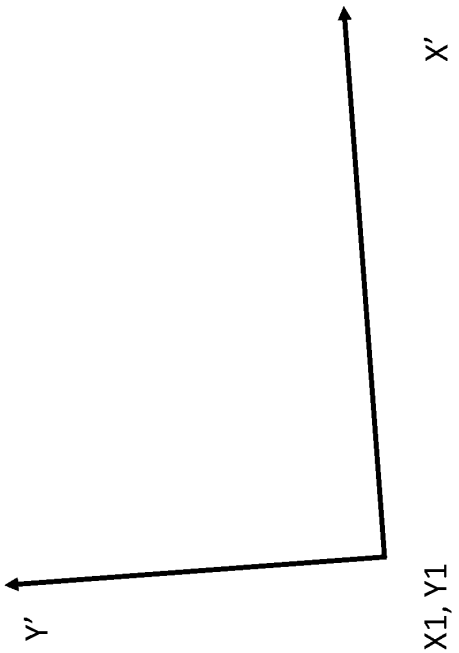


FIG. 9C

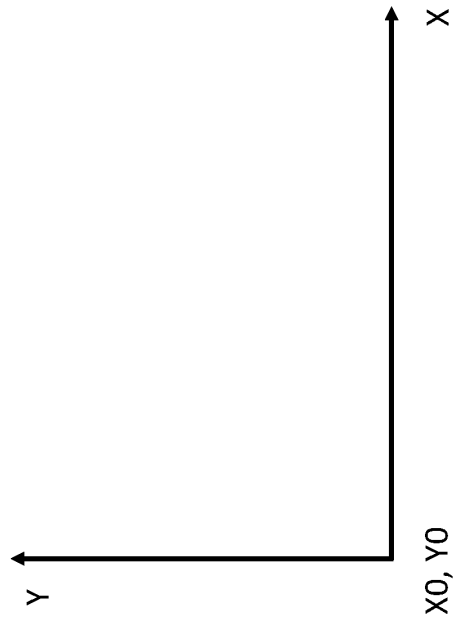


FIG. 9B

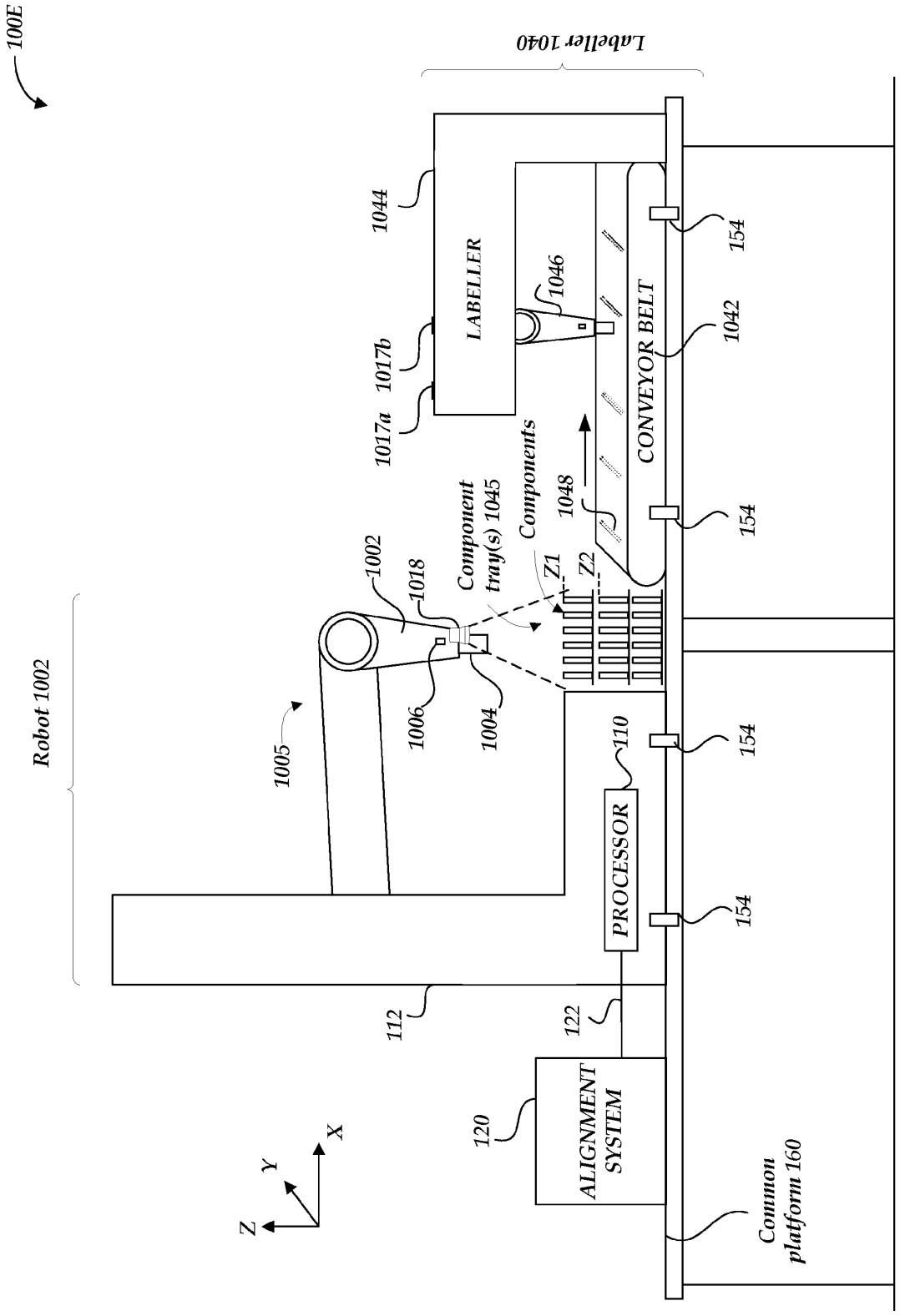

100E
Labeller 1040
1044
LABELLER
1046
1017b
1017a
CONVEYOR BELT
1042
154
Components
1048
Component tray(s) 1045
Z1
Z2
1002
1018
Robot 1002
1005
1006
1004
110
PROCESSOR
112
122
120
ALIGNMENT SYSTEM
Common platform 160
Y
X
Z

FIG. 10

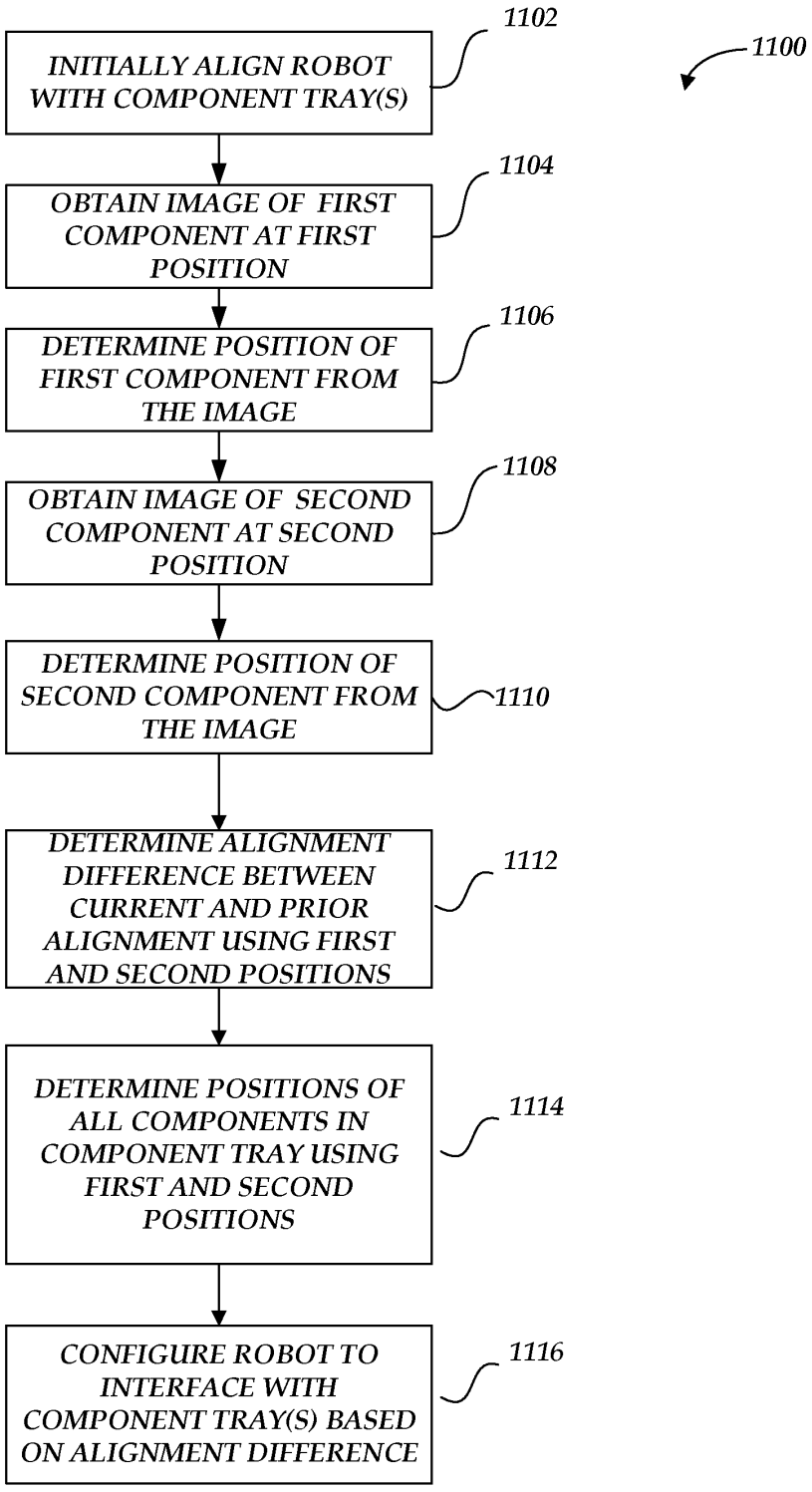

1100
1102
INITIALLY ALIGN ROBOT WITH COMPONENT TRAY(S)
1104
OBTAIN IMAGE OF FIRST COMPONENT AT FIRST POSITION
1106
DETERMINE POSITION OF FIRST COMPONENT FROM THE IMAGE
1108
OBTAIN IMAGE OF SECOND COMPONENT AT SECOND POSITION
DETERMINE POSITION OF SECOND COMPONENT FROM THE IMAGE
1110
DETERMINE ALIGNMENT DIFFERENCE BETWEEN CURRENT AND PRIOR ALIGNMENT USING FIRST AND SECOND POSITIONS
1112
DETERMINE POSITIONS OF ALL COMPONENTS IN COMPONENT TRAY USING FIRST AND SECOND POSITIONS
1114
CONFIGURE ROBOT TO INTERFACE WITH COMPONENT TRAY(S) BASED ON ALIGNMENT DIFFERENCE
1116

FIG. 11

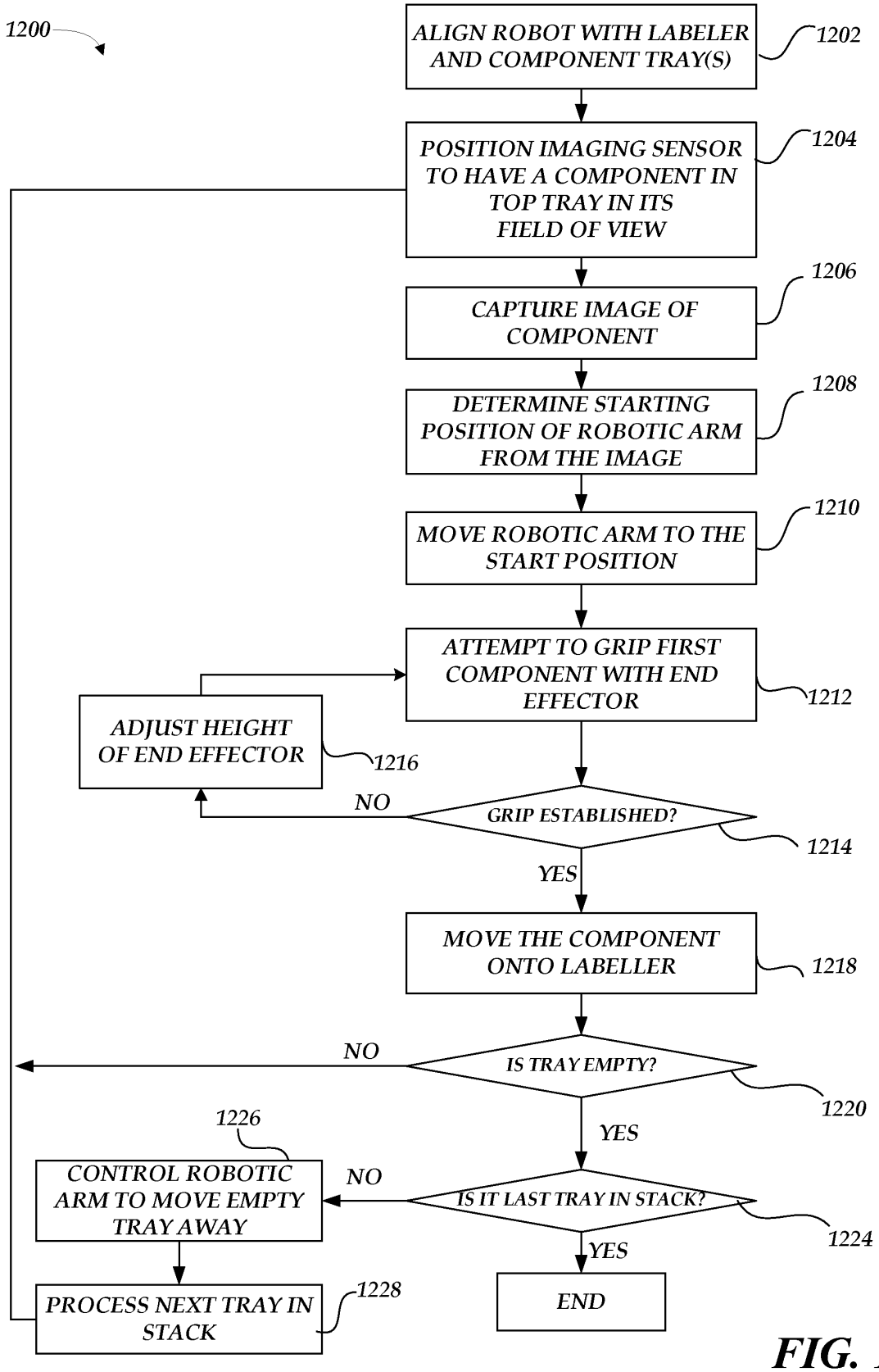

1200
ALIGN ROBOT WITH LABELER AND COMPONENT TRAY(S)
1202
POSITION IMAGING SENSOR TO HAVE A COMPONENT IN TOP TRAY IN ITS FIELD OF VIEW
1204
CAPTURE IMAGE OF COMPONENT
1206
DETERMINE STARTING POSITION OF ROBOTIC ARM FROM THE IMAGE
1208
MOVE ROBOTIC ARM TO THE START POSITION
1210
ATTEMPT TO GRIP FIRST COMPONENT WITH END EFFECTOR
1212
ADJUST HEIGHT OF END EFFECTOR
1216
NO
GRIP ESTABLISHED?
1214
YES
MOVE THE COMPONENT ONTO LABELLER
1218
NO
IS TRAY EMPTY?
1220
YES
1226
CONTROL ROBOTIC ARM TO MOVE EMPTY TRAY AWAY
NO
IS IT LAST TRAY IN STACK?
1224
YES
PROCESS NEXT TRAY IN STACK
1228
END

FIG. 12

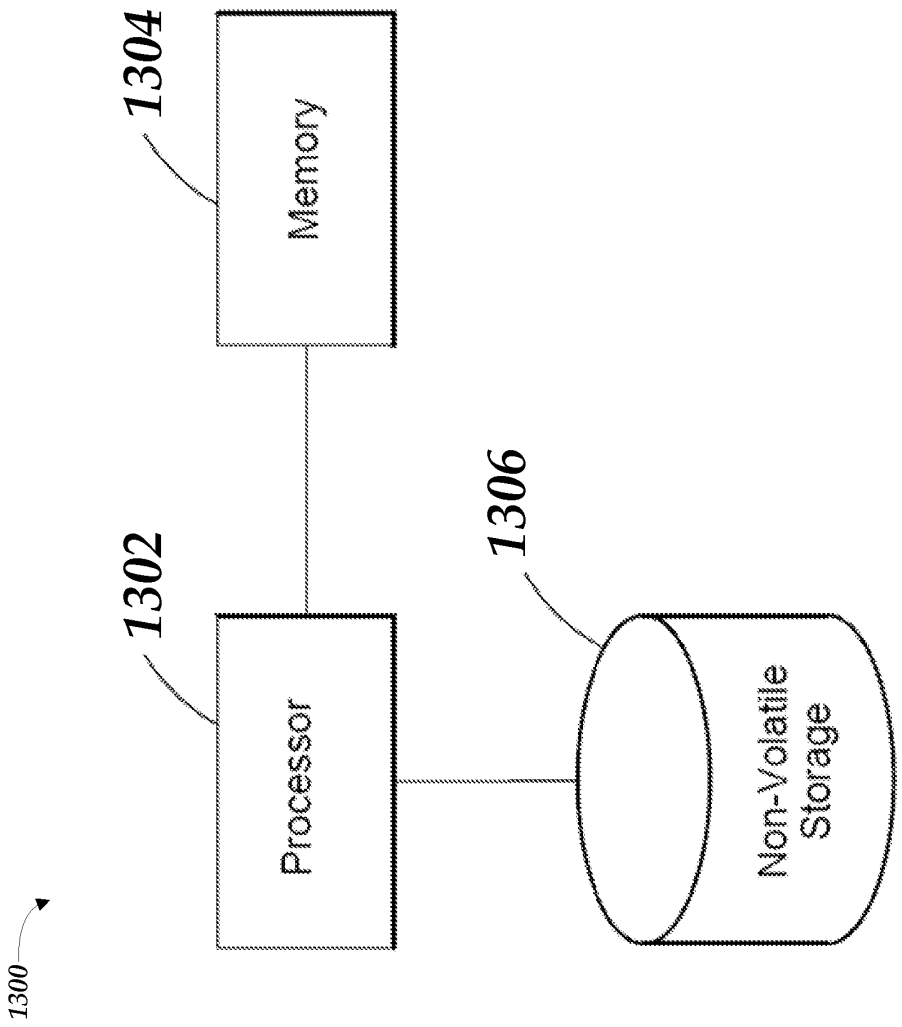


FIG. 13