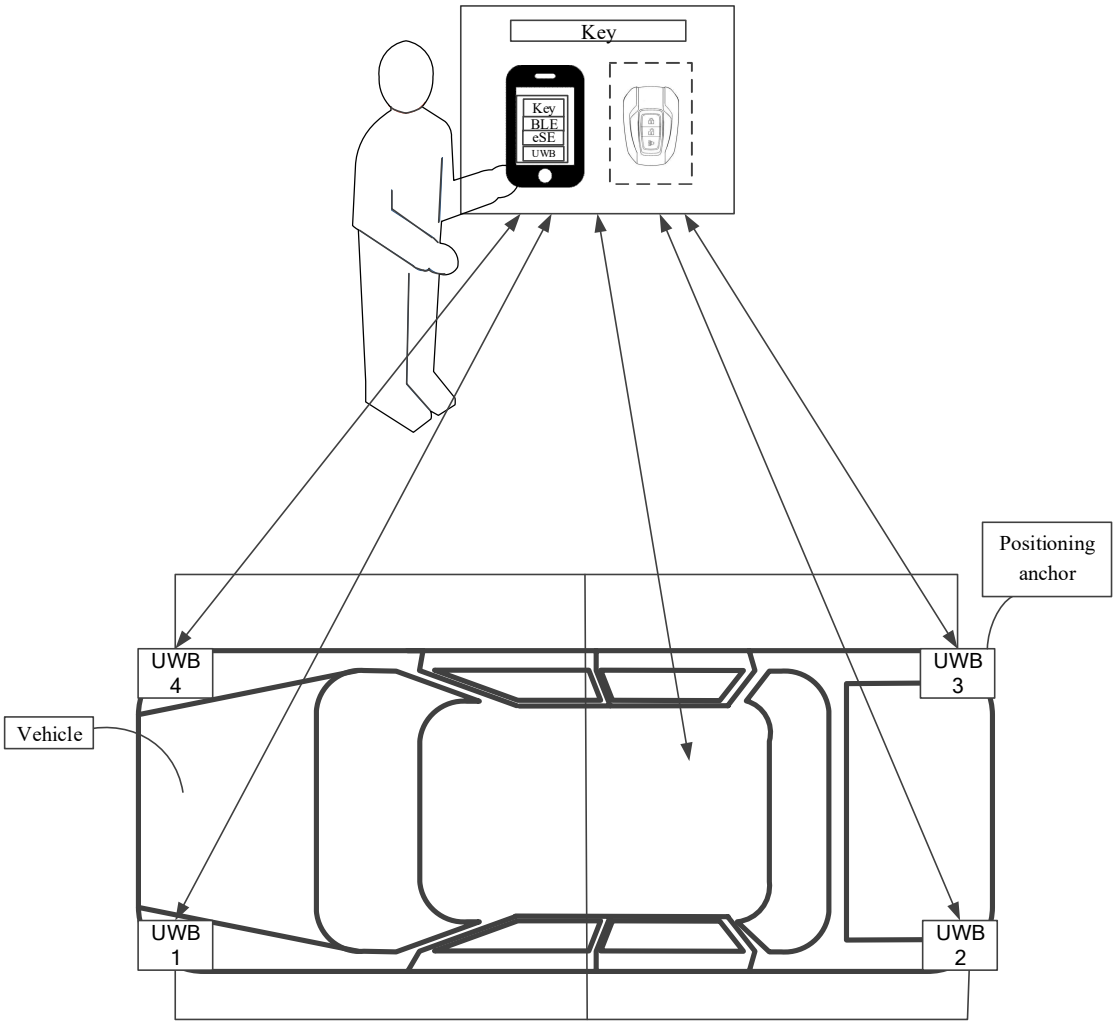

Key
Key
BLE
eSE
UWB
Positioning anchor
UWB 4
UWB 3
Vehicle
UWB 1
UWB 2

FIG. 1

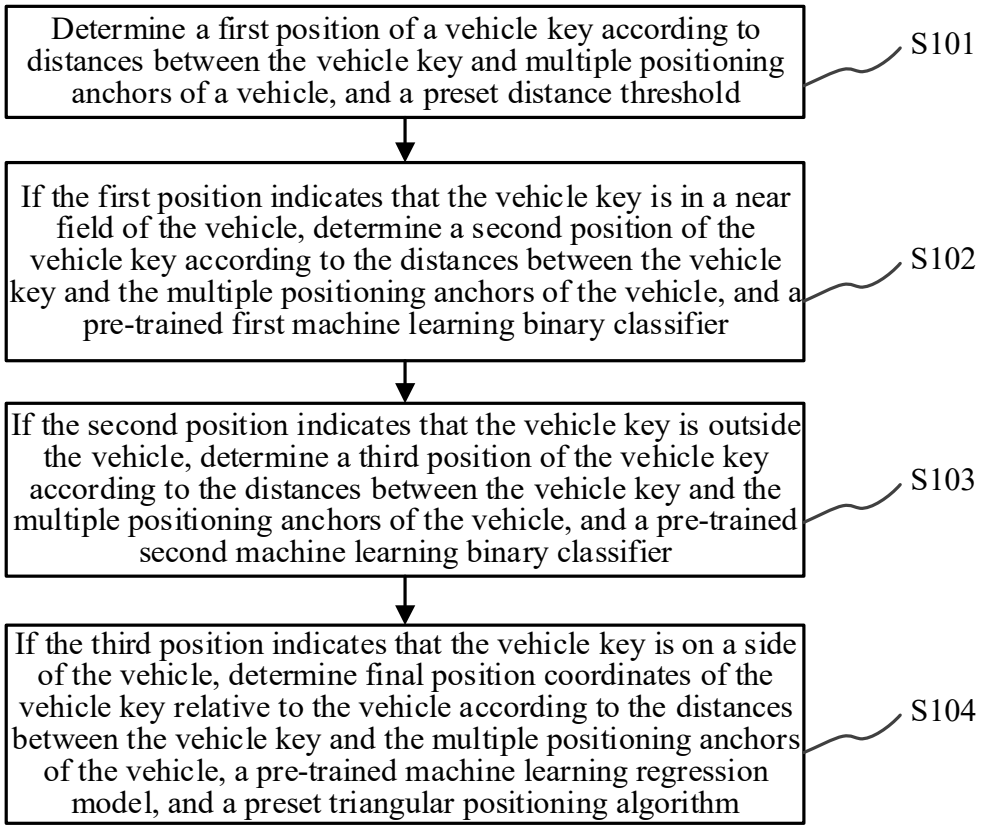

Determine a first position of a vehicle key according to distances between the vehicle key and multiple positioning anchors of a vehicle, and a preset distance threshold
S101
If the first position indicates that the vehicle key is in a near field of the vehicle, determine a second position of the vehicle key according to the distances between the vehicle key and the multiple positioning anchors of the vehicle, and a pre-trained first machine learning binary classifier
S102
If the second position indicates that the vehicle key is outside the vehicle, determine a third position of the vehicle key according to the distances between the vehicle key and the multiple positioning anchors of the vehicle, and a pre-trained second machine learning binary classifier
S103
If the third position indicates that the vehicle key is on a side of the vehicle, determine final position coordinates of the vehicle key relative to the vehicle according to the distances between the vehicle key and the multiple positioning anchors of the vehicle, a pre-trained machine learning regression model, and a preset triangular positioning algorithm
S104

FIG. 2

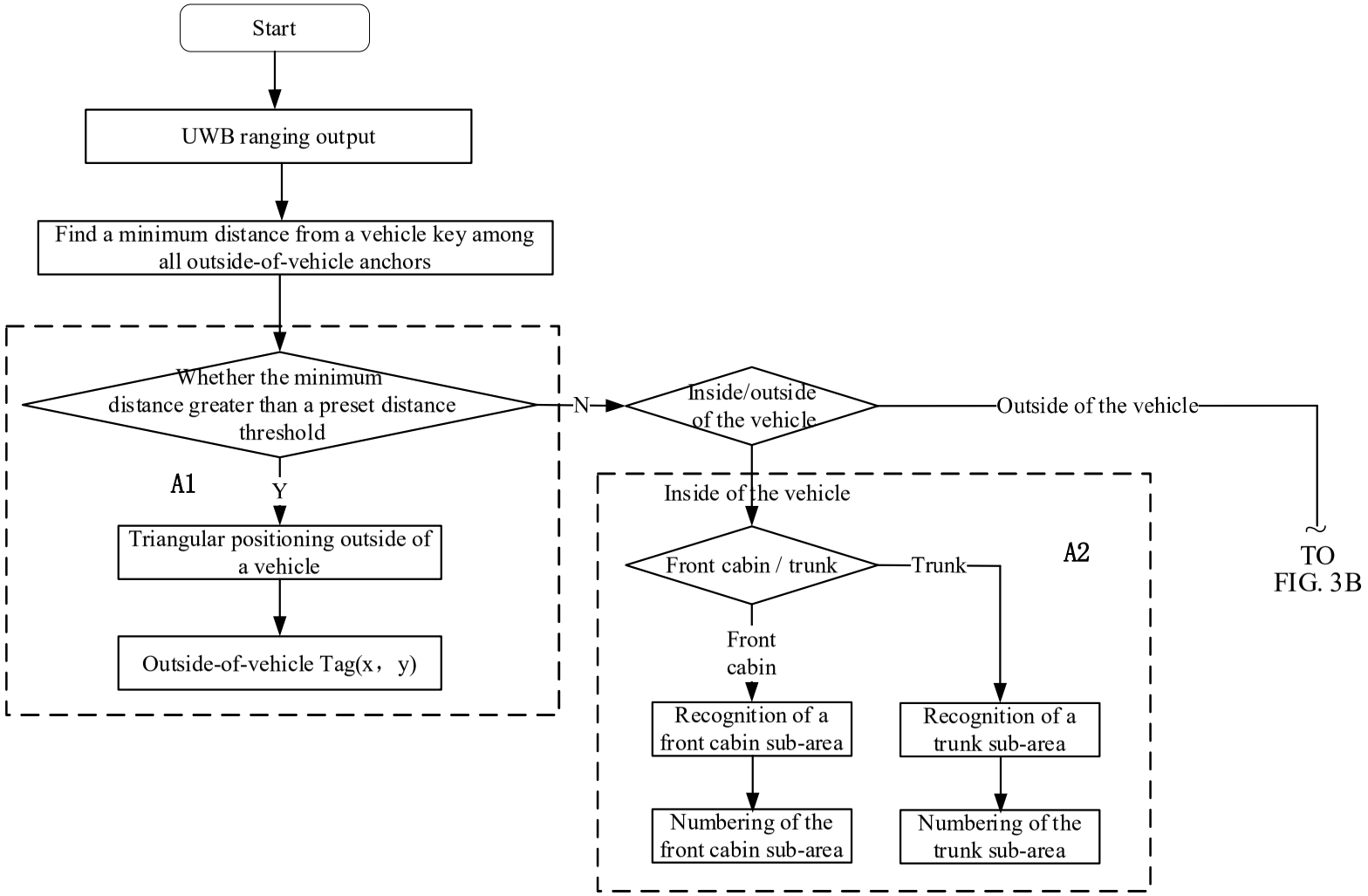

Start
UWB ranging output
Find a minimum distance from a vehicle key among all outside-of-vehicle anchors
Whether the minimum distance greater than a preset distance threshold
N
Y
A1
Triangular positioning outside of a vehicle
Outside-of-vehicle Tag(x，y)
Inside/outside of the vehicle
Outside of the vehicle
TO FIG. 3B
Inside of the vehicle
A2
Front cabin / trunk
Trunk
Front cabin
Recognition of a front cabin sub-area
Recognition of a trunk sub-area
Numbering of the front cabin sub-area
Numbering of the trunk sub-area

FIG. 3A

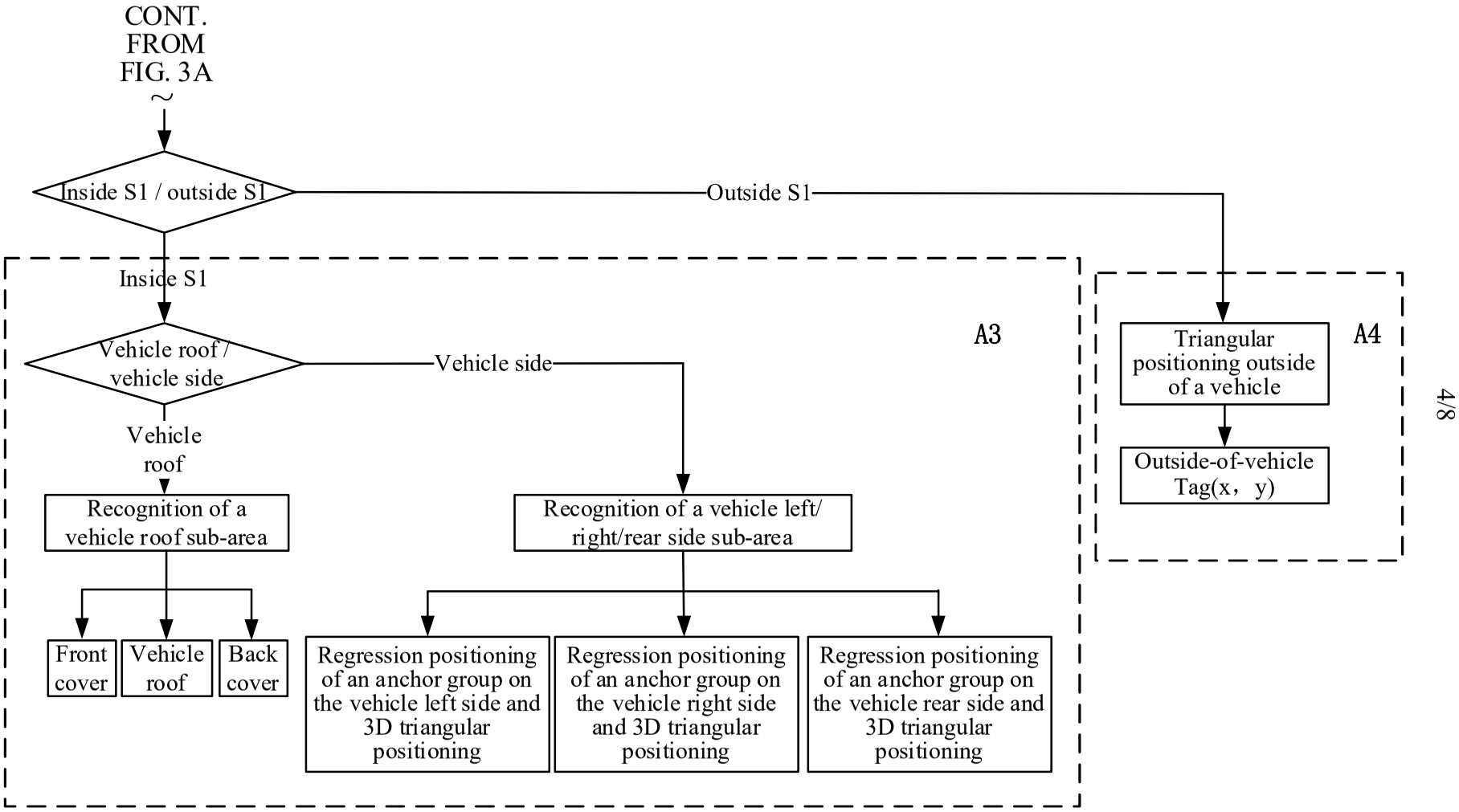

CONT.
FROM
FIG. 3A
Inside S1 / outside S1
Outside S1
Inside S1
A3
Vehicle roof / vehicle side
Vehicle side
Vehicle roof
Recognition of a vehicle roof sub-area
Recognition of a vehicle left/ right/rear side sub-area
Front cover
Vehicle roof
Back cover
Regression positioning of an anchor group on the vehicle left side and 3D triangular positioning
Regression positioning of an anchor group on the vehicle right side and 3D triangular positioning
Regression positioning of an anchor group on the vehicle rear side and 3D triangular positioning
A4
Triangular positioning outside of a vehicle
Outside-of-vehicle Tag(x, y)

FIG. 3B

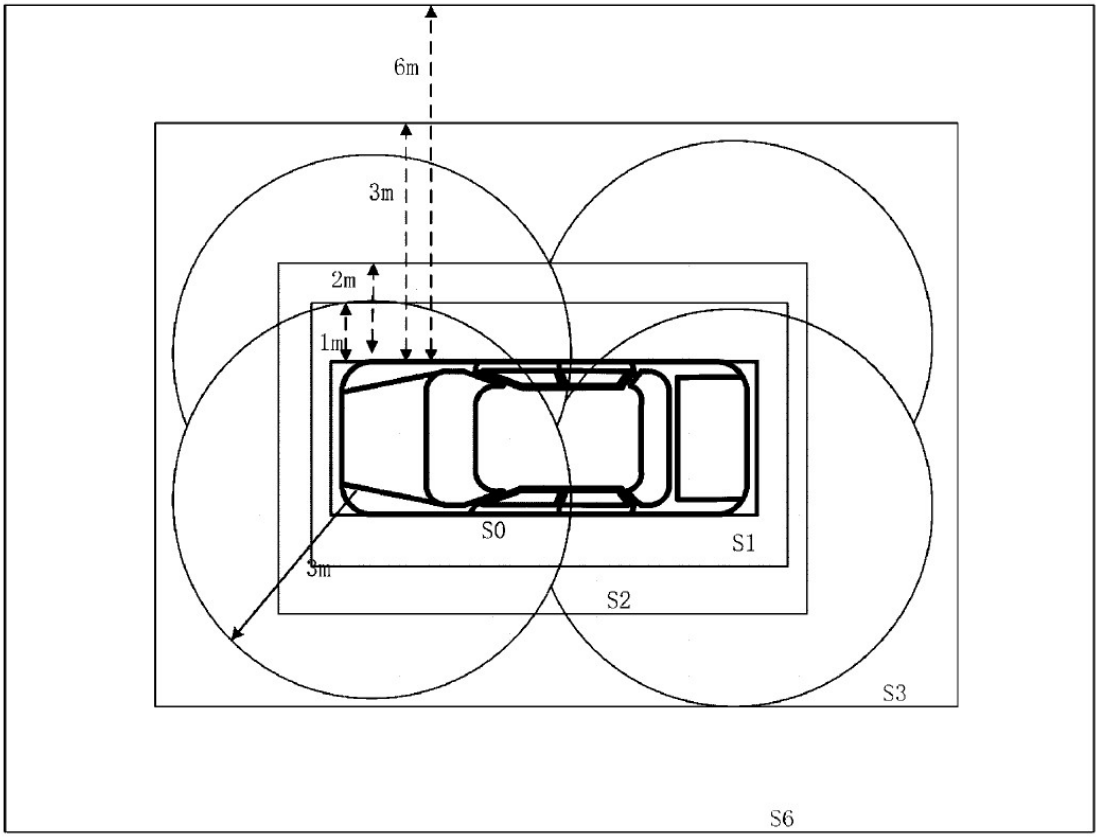

6m
3m
2m
1m
S0
S1
3m
S2
S3
S6

FIG. 4

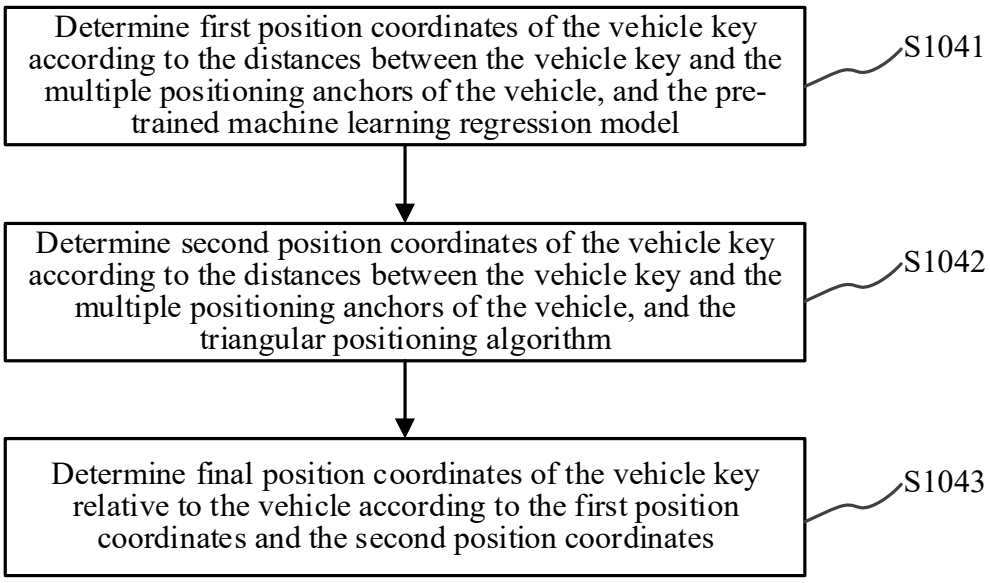

Determine first position coordinates of the vehicle key according to the distances between the vehicle key and the multiple positioning anchors of the vehicle, and the pre-trained machine learning regression model
S1041
Determine second position coordinates of the vehicle key according to the distances between the vehicle key and the multiple positioning anchors of the vehicle, and the triangular positioning algorithm
S1042
Determine final position coordinates of the vehicle key relative to the vehicle according to the first position coordinates and the second position coordinates
S1043

FIG. 5

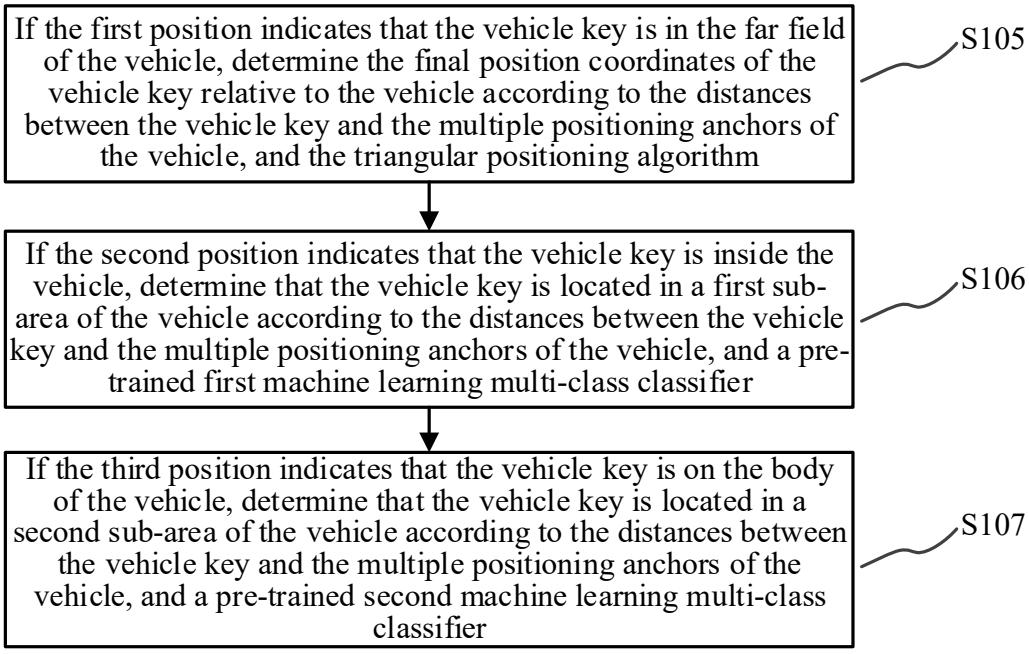

If the first position indicates that the vehicle key is in the far field of the vehicle, determine the final position coordinates of the vehicle key relative to the vehicle according to the distances between the vehicle key and the multiple positioning anchors of the vehicle, and the triangular positioning algorithm
S105
If the second position indicates that the vehicle key is inside the vehicle, determine that the vehicle key is located in a first sub-area of the vehicle according to the distances between the vehicle key and the multiple positioning anchors of the vehicle, and a pre-trained first machine learning multi-class classifier
S106
If the third position indicates that the vehicle key is on the body of the vehicle, determine that the vehicle key is located in a second sub-area of the vehicle according to the distances between the vehicle key and the multiple positioning anchors of the vehicle, and a pre-trained second machine learning multi-class classifier
S107

FIG. 6

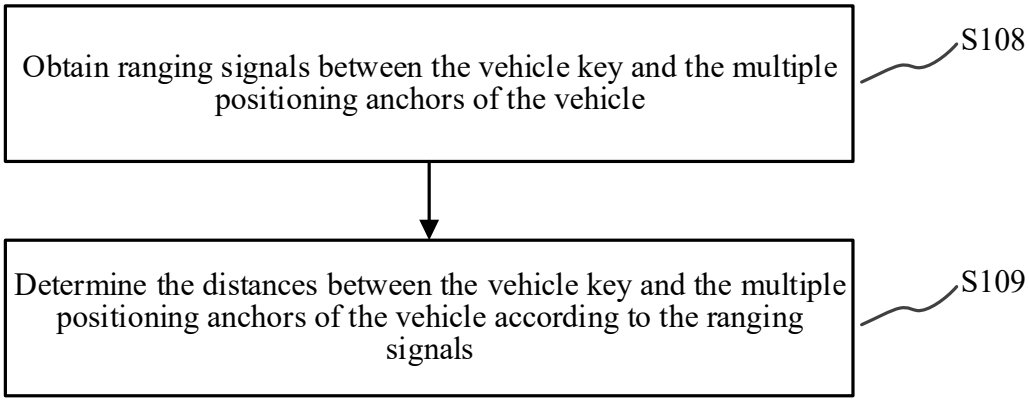

Obtain ranging signals between the vehicle key and the multiple positioning anchors of the vehicle
S108
Determine the distances between the vehicle key and the multiple positioning anchors of the vehicle according to the ranging signals
S109

FIG. 7

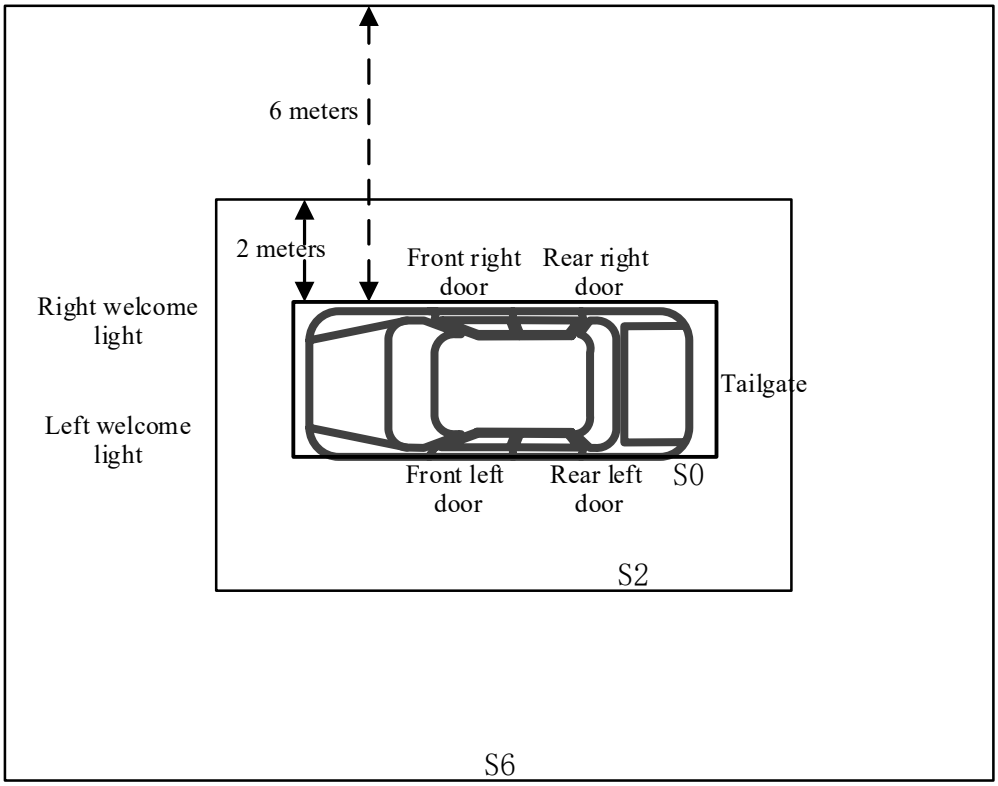


FIG. 8

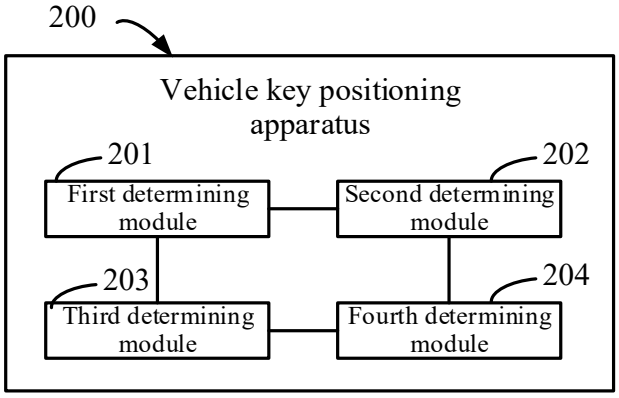


FIG. 9

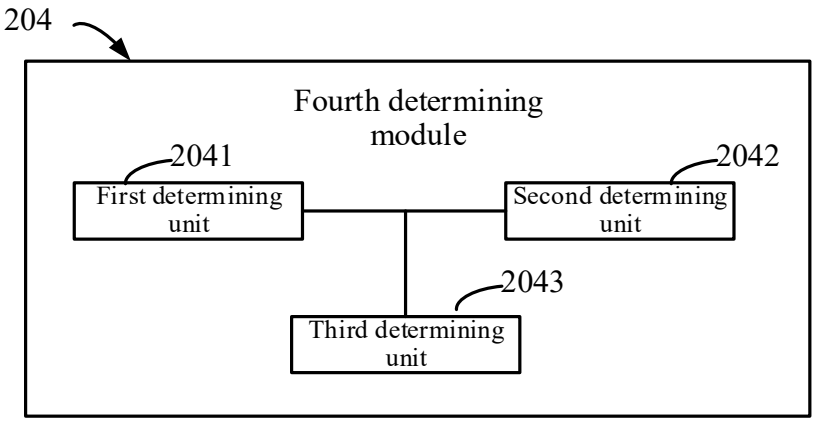


FIG. 10

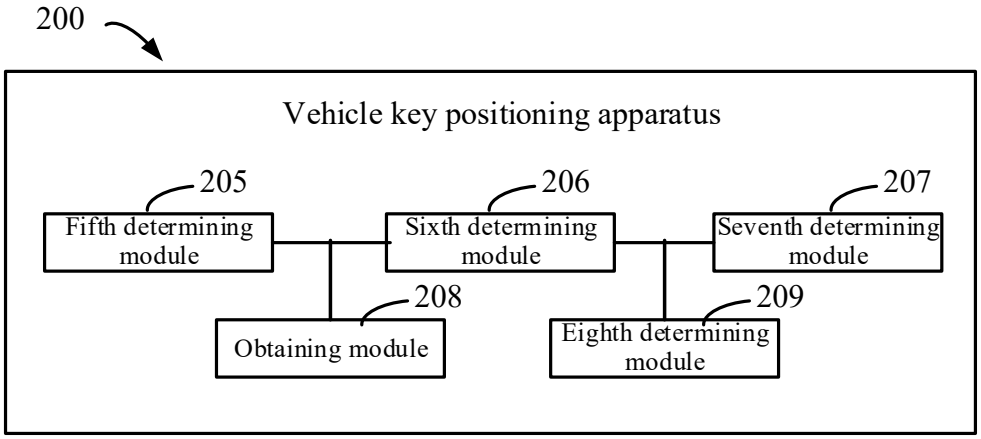

200
Vehicle key positioning apparatus
205
Fifth determining module
206
Sixth determining module
207
Seventh determining module
208
Obtaining module
209
Eighth determining module

FIG. 11

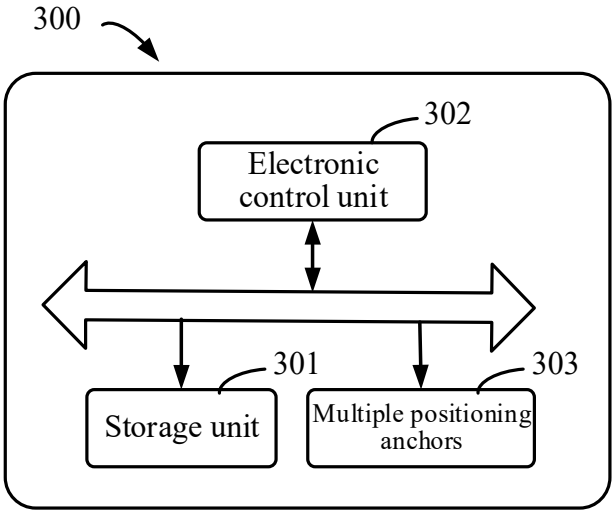

300
302
Electronic control unit
301
Storage unit
303
Multiple positioning anchors

FIG. 12