Claims

[Claim 1]

A bias estimation device, comprising:

a determination unit configured to determine whether a forklift is stationary based on a measurement value from a first sensor configured to detect information regarding movement of the forklift and a measurement value from a second sensor configured to detect information regarding a cargo handling device included in the forklift;

an accumulation unit configured to accumulate an IMU measurement value that is a measurement value from an inertial measurement unit included in the forklift when the determination unit determines that the forklift is stationary and stop accumulation of the IMU measurement value when the determination unit determines that the forklift is not stationary;

a sample number monitoring unit configured to determine that a sufficient number of samples for calculating the bias of the IMU measurement values has been obtained when the number of accumulated IMU measurement values accumulated in the accumulation unit becomes equal to or greater than the threshold;

a calculation unit configured to calculate a bias of the IMU measurement value based on the IMU measurement value accumulated in the accumulation unit when the sample number monitoring unit determines that a sufficient number of samples has been obtained;

an end determination unit configured to delete the IMU measurement value accumulated in the accumulation unit when the calculation unit ends the bias calculation or when the determination unit determines that the forklift is not stationary.

[Claim 2]

The bias estimation device according to claim 1, wherein the determination unit determines that the forklift is stationary when a first condition that a measurement value from the first sensor does not indicate that the forklift is moving and that a measurement value from the second sensor does not indicate that the forklift is in cargo handling operation is satisfied and determines that the forklift is not stationary when the first condition is not satisfied.

[Claim 3]

The bias estimation device according to claim 2, wherein the determination unit acquires information on whether the inertial measurement unit is activated, determines that the forklift is stationary when the inertial measurement unit is activated and the first condition is satisfied, and determines that the forklift is not stationary otherwise.

[Claim 4]

The bias estimation device according to claims 1 or 2, wherein the determination unit acquires information on whether the forklift is being charged, determines that the forklift is stationary when the forklift is being charged, and determines that the forklift is not stationary when the forklift is not being charged.

[Claim 5]

The bias estimation device according to claims 1 or 2, further comprising

a sudden change portion detection unit configured to detect a sudden change portion of the IMU measurement value accumulated in the accumulation unit, wherein

the accumulation unit deletes the IMU measurement value at the sudden change portion and before and after the sudden change portion detected by the sudden change portion detection unit,

the calculation unit calculates the bias based on the IMU measurement value remaining after deletion;

the sudden change portion detection unit specifies, as a sudden change portion, a section including data having a deviation of equal to or greater than a certain width from the average of the IMU measurement values in a temporally continuous section in the accumulated data.

[Claim 6]

The bias estimation device according to claims 1 or 2, further comprising

a sudden change portion detection unit configured to determine an outlier and a normal value applying a random sample consensus (RANSAC) algorithm to the accumulated IMU measurement value data, wherein

the accumulation unit deletes the IMU measurement value that is determined to be an outlier and the values before and after by the sudden change portion detection unit,

the calculation unit calculates the bias based on the IMU measurement value remaining after deletion.

[Claim 7]

The bias estimation device according to claim 5, wherein

the sudden change portion detection unit learns the IMU measurement value not including the sudden change portion and the IMU measurement value deleted, construct a model to distinguish them, and determines whether the IMU measurement value accumulated in the accumulation unit is an IMU measurement value that belongs to the deleted IMU measurement value or not based on the model, and

the accumulation unit deletes the IMU measurement value determined to belong to the deleted IMU measurement value and data before and after the IMU measurement value.

[Claim 8]

The bias estimation device according to claims 1 or 2, further comprising:

a temperature value accumulation unit configured to accumulate time-series temperature data regarding an ambient temperature of the forklift; and

a temperature change detection unit configured to detect whether the ambient temperature has changed by equal to or greater than a reference based on the time-series temperature data accumulated in the temperature value accumulation unit, wherein

the accumulation unit accumulates the IMU measurement value when the temperature change detection unit determines that the ambient temperature has changed by equal to or greater than the reference and the determination unit determines that the forklift is stationary.

[Claim 9]

The bias estimation device according to claims 1 or 2, wherein

the first sensor is a sensor that detects a rotation speed and/or a steering angle of a tire included in the forklift, and

the second sensor is a sensor that detects a lifting height position of a fork included in the forklift and/or a weight of a cargo loaded on the fork.

[Claim 10]

A bias estimation device, comprising:

a determination unit configured to acquire information on whether a forklift is being charged, determine that the forklift is stationary when the forklift is being charged, and determine that the forklift is not stationary when the forklift is not being charged;

an accumulation unit configured to accumulate an IMU measurement value that is a measurement value from an inertial measurement unit included in the forklift when the determination unit determines that the forklift is stationary and stop accumulation of the IMU measurement value when the determination unit determines that the forklift is not stationary;

a sample number monitoring unit configured to determine that a sufficient number of samples for calculating the bias of the IMU measurement values has been obtained when the number of accumulated IMU measurement values accumulated in the accumulation unit becomes equal to or greater than the threshold;

a calculation unit configured to calculate a bias of the IMU measurement value based on the IMU measurement value accumulated in the accumulation unit when the sample number monitoring unit determines that a sufficient number of samples has been obtained; and

an end determination unit configured to delete the IMU measurement value accumulated in the accumulation unit when the calculation unit ends the bias calculation or when the determination unit determines that the forklift is not stationary.

[Claim 11]

A forklift, comprising:

a traveling body;

a cargo handling device;

the bias estimation device according to claims 1 or 2; and

a positioning device configured to compensate the IMU measurement value by using the bias estimation device and determine a position of the forklift based on the IMU measurement value after compensation.

[Claim 12]

A bias estimation method, comprising:

a step of repeatedly determining whether a forklift is stationary based on a measurement value from a first sensor configured to detect information regarding movement of the forklift and a measurement value from a second

sensor configured to detect information regarding a cargo handling device included in the forklift;

a step of accumulating an IMU measurement value that is a measurement value from an inertial measurement unit included in the forklift when the forklift is determined to be stationary in the step of determining;

a step of stopping accumulation of the IMU measurement value when the forklift is determined to be not stationary in the step of determining and deleting the accumulated IMU measurement value;

a step of determining that a sufficient number of samples for calculating the bias of the IMU measurement values has been obtained when the number of accumulated IMU measurement values accumulated becomes equal to or greater than the threshold;

a step of calculating a bias of the IMU measurement value based on the IMU measurement value accumulated when it is determined that a sufficient number of samples has been obtained in the step of determining that a sufficient number of samples have been obtained; and

a step of deleting the accumulated IMU measurement value when the bias calculation is ended.

[Claim 13]

A program that causes a computer to execute:

a step of repeatedly determining whether a forklift is stationary based on a measurement value from a first sensor configured to detect information regarding movement of the forklift and a measurement value from a second sensor configured to detect information regarding a cargo handling device included in the forklift;

a step of accumulating an IMU measurement value that is a measurement value from an inertial measurement unit included in the forklift when the forklift is determined to be stationary in the step of determining;

a step of stopping accumulation of the IMU measurement value when the forklift is determined to be not stationary in the step of determining and deleting the accumulated IMU measurement value;

a step of determining that a sufficient number of samples for calculating the bias of the IMU measurement values has been obtained when the number of accumulated IMU measurement values accumulated becomes equal to or greater than the threshold;

a step of calculating a bias of the IMU measurement value based on the IMU measurement value accumulated when it is determined that a sufficient

number of samples has been obtained in the step of determining that a sufficient number of samples have been obtained; and

a step of deleting the accumulated IMU measurement value when the bias calculation is ended.