

An Improved Classic Washout Algorithm Based on Tilted Coordinated Channel for Ship Motion Simulator

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Abstract. The motion washout aims to bring the actual movement of the ship back to motion simulator, and to provide as real motion as possible in the limited space of the simulator. The difficulty of the classic washout algorithm lies in the choice of filter parameters. If the parameters are too small, the effect of the simulation will not be achieved, and if the parameters are too large, the effect of the simulated continuous acceleration will be reduced, resulting in false intimation. This paper redesigned the tilt coordination channel to match the effects of simulating sustained acceleration and the reduce false intimation.

1. Introduction

The washout algorithm is an important part of the motion simulator, which can convert the actual motion parameters of the ship into the position and pose information of the six degree of freedom platform [1]. The classical washout algorithm has been widely used in the dynamic simulation field because it is simple in form, easy to adjust, fast in execution, and fast in feedback [2, 3]. However, if the parameters in the classic washout algorithm are not properly selected, the washout effect will not be achieved. By redesigning the tilt coordination channel, it can meet the effect of simulating continuous acceleration, and can reduce the effect of false intimation and make up for the defects of the classic washout algorithm [4].

2. The structure of the improved washout algorithm

The classic washout algorithm divides the motion of the simulator into three parts: high pass acceleration channel, low pass acceleration channel and high pass speed channel, as shown in Fig. 1 [5]. The improved washout algorithm with new tilted coordinated channel as shown in Fig. 2.



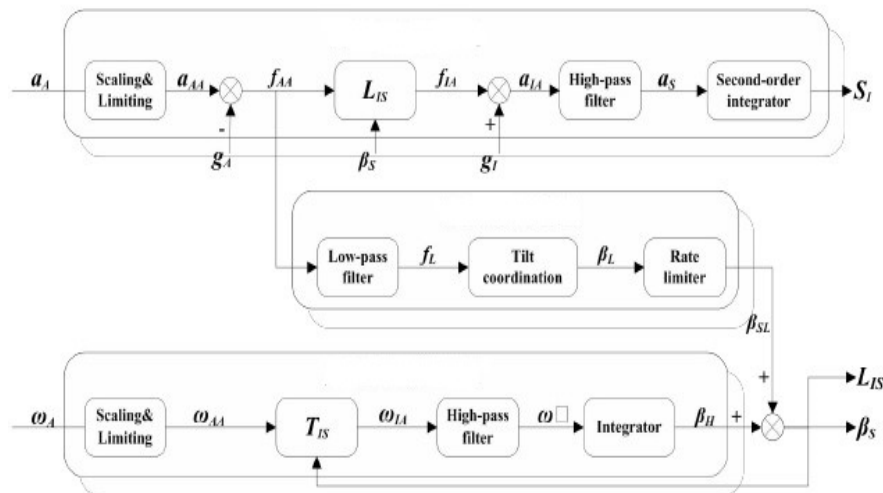


Figure 1. Classical washout algorithm principle.

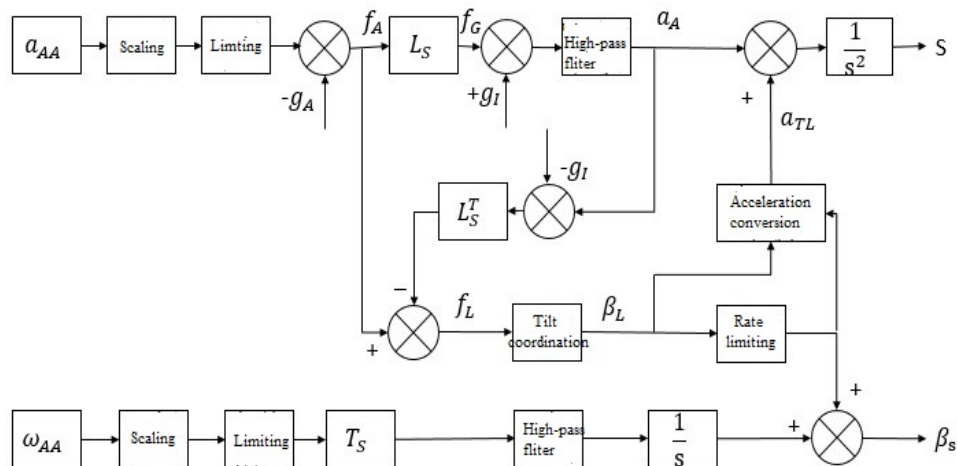


Figure 2. Improved washout algorithm principle.

3. Design of improved classical washout algorithm

Redesigned for the problem of tilted channels, the improvement is to eliminate the phase delay caused by the low-pass filter that some of the continuous acceleration that needs to be simulated cannot pass, and compensate the loss due to the angular velocity limit by the translational motion channel. The continuous acceleration enhances the effect of the overall washout feel acceleration.

Improvements to tilt coordination: The introduced low-pass acceleration channel signal takes into account the effects of high-pass acceleration after washing out, and then washes out the tilt angle according to the principle of tilt coordination. The a_G of the high-pass acceleration channel is the absolute acceleration of the platform, so it needs to be converted into relative acceleration, and the improved low-pass acceleration signal of the improved inclined channel is shown in Eq. 1.

$$f_L = f_A - L_S^T(a_G - g_I) \quad (1)$$

The use of the tilt channel angular velocity limiter, most of the angular velocity before the limiting is beyond the threshold of the human sensory system set by the limiter, after passing the limiter, the tilt angle of the pass is reduced, therefore, the continuous acceleration that needs to be simulated is not obtained. The tilt angular velocity that has not passed the limiter is simulated by the high-pass

translational acceleration, which is converted into a_{TL} by acceleration, and then compensated to the high-pass translational acceleration channel. The acceleration conversion module is shown in Eq. 2 and Eq. 3.

$$\beta_L = \left(\frac{f_L^x}{g}, -\frac{f_L^y}{g}, 0 \right) \quad (2)$$

$$a_{TL} = (\beta_L - \beta_{SL})g + g_I \quad (3)$$

4. Simulation and analysis of improved wash algorithm

Improving the classical washout algorithm according to the design of Fig. 2, and build a simulation model in matlab/simulink. To simulate various acceleration actions during motion, select a random Gaussian white noise input with an intensity of 2dbw as the simulated longitudinal acceleration, as shown in Fig. 3, and input the pitch angular velocity to 0.

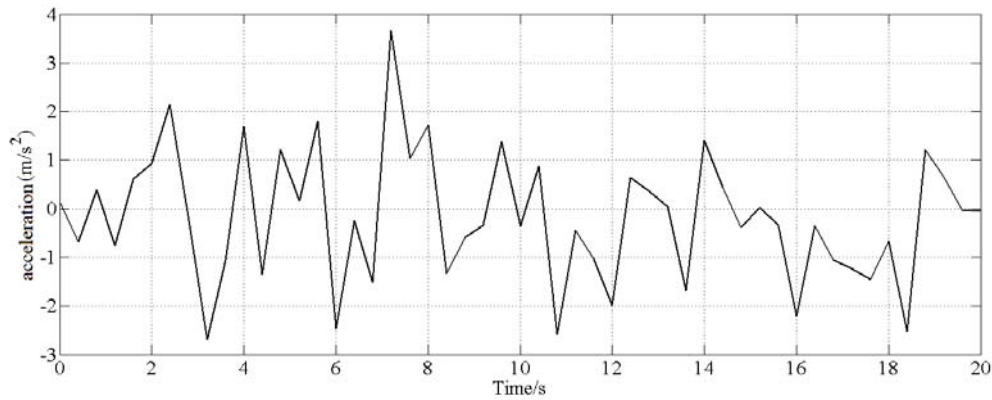


Figure 3. Input Gaussian white noise acceleration.

Fig. 4 is a graph of the tilt coordinated acceleration of the improved algorithm and the classical algorithm with respect to the reference acceleration. It can be seen from the figure that the improved algorithm uses a new source of low-pass acceleration, which greatly reduces the phase delay of the tilt-coordinated acceleration, and can well approach the extreme points of the reference curve, thus effectively overcoming the false intimation of longitudinal sensory acceleration.

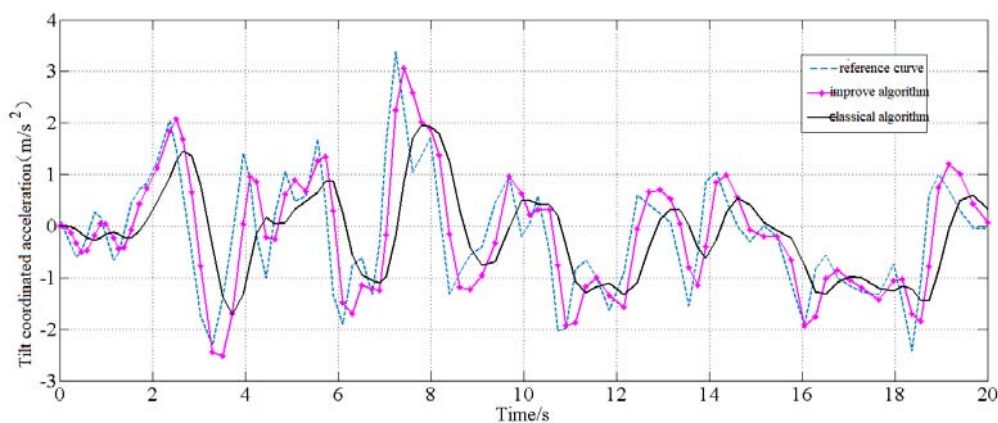


Figure 4. Input Gaussian white noise acceleration.

It can be seen from Fig. 5 and Fig. 6 that the angular velocity of the improved algorithm washed out by the oblique coordination channel is more reasonable than the classical algorithm, and the sustained

acceleration of the tilt coordination is simulated to the maximum extent. The angular displacement of the washout is not significantly increased compared to the classical washout algorithm, ensuring that tilt coordination occurs at small angles. The absolute value of the perceived angular velocity of the washout is limited to $3.6^\circ/\text{s}$, the human body can not feel the angular velocity of the pitch direction, which proves that the improved algorithm does not produce false hints in the pitch direction.

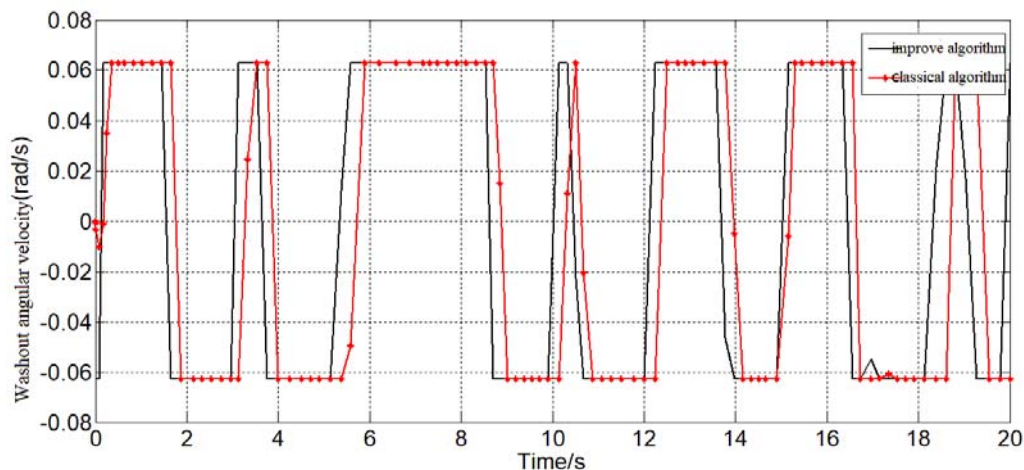


Figure 5. Washout angular velocity.

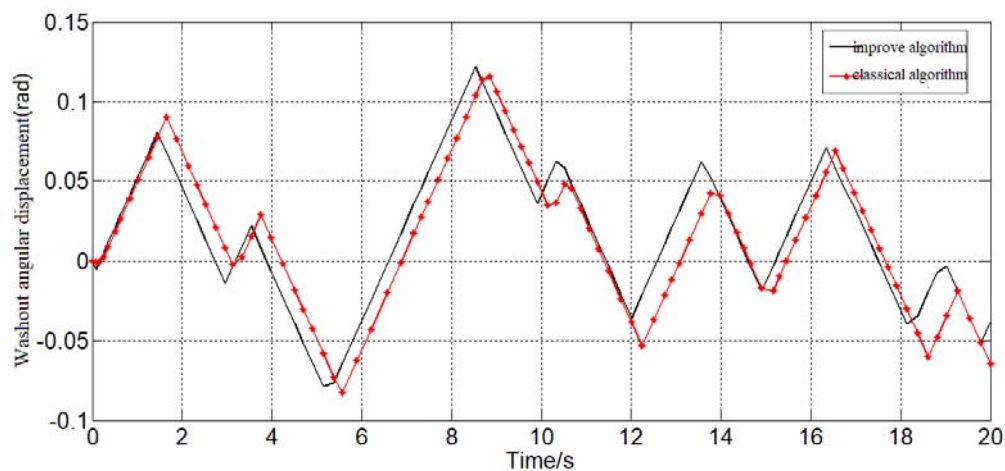


Figure 6. Washout angular displacement.

The acceleration of the washout consists of the translational acceleration of the translational motion channel and the continuous acceleration of the tilt coordination.

As can be seen from Fig. 7 and Fig. 8, the improved algorithm effectively overcomes the shortcomings of the classical washout algorithm, resulting in a small phase delay in the sensed acceleration of the washout, and the perceived acceleration error of the washout is much smaller than the threshold of the otolith. Therefore, the human body does not feel the false intimation caused by the longitudinal acceleration, which proves that the improved algorithm of the design has high reliability.

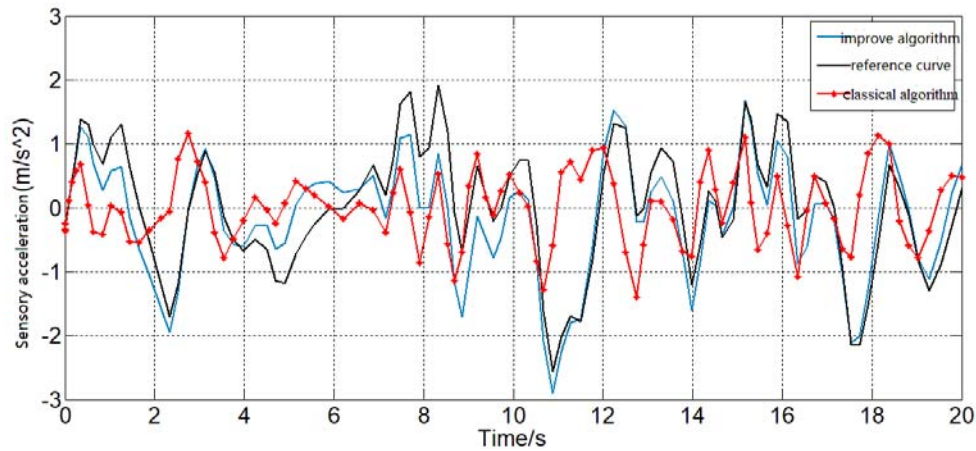


Figure 7. Sensory acceleration.

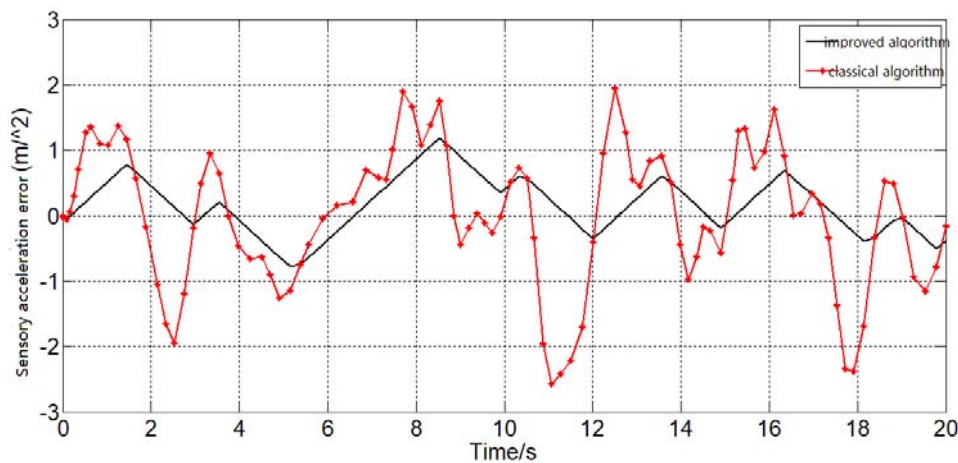


Figure 8. Sensory acceleration error.

5. Conclusion

In this paper, the tilt coordination channel is redesigned, and the obtained washout angular velocity simulates the continuous acceleration of the tilt coordination channel to the maximum extent compared with the classical washout algorithm. The resulting washout sensation acceleration produces only a small phase delay, and the washout sensation acceleration error is much smaller than the otolith threshold, eliminating false intimation. It is proved that the improved algorithm can improve the effect of motion washout and eliminate the false intimation problem caused by the classic washout algorithm.

Acknowledgments

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