Real-Time Low-Latency IMU Sensor Fusion Algorithm Settings

1. IMU weight config

Selects the overall balance between IMU dead reckoning and ultrasonic position corrections. Options: Low (US corrections dominate — output closely follows US positions, faster convergence, noisier output), Medium (balanced default), High (IMU dead reckoning dominates — smooth output, slower correction). Select User-defined to control the individual balance parameters (items 2, 3, 4) manually instead of using a preset.

2. Decay rate of drift toward zero, Hz

Rate (1/s) at which the accumulated position offset between the IMU trajectory and the ultrasonic track is driven back to zero. Higher values make the output converge faster to the US position; lower values let the IMU dead-reckoning influence last longer, giving a smoother but slower-correcting output. Active only when IMU weight config is set to User-defined.

3. Velocity blending weight

At each ultrasonic fix, the IMU-integrated velocity is blended toward the velocity derived from two consecutive US positions. This parameter sets the maximum blend fraction: 0.0 keeps the IMU velocity unchanged; 1.0 replaces it fully with the US-derived value. The actual blend is also scaled by the reliability of the fix. Active only when IMU weight config is set to User-defined.

4. US jump alpha for outlier suppress

Fraction of the position discrepancy between the current IMU position and an incoming US fix that is applied immediately at the moment the fix is processed. Values closer to 1.0 snap the output quickly to the US position; lower values spread the correction over time through the drift-decay mechanism. Active only when IMU weight config is set to User-defined.

5. Hedge mount offset, degrees

The angle between the physical beacon pair axis (line connecting the two beacons in a mobile pair) and the IMU body X axis. Must be set correctly for the continuous yaw correction from paired beacons to align with the true heading direction. For example, 90° means the pair axis aligns with the IMU Y axis.

6. Extrapolate US position (enabled/disabled)

When enabled, the ultrasonic position is shifted forward in time by the processing delay between the ranging measurement and its application (~68 ms) using the current IMU velocity. This eliminates a systematic backward-step artifact in the output that otherwise appears at every US fix during high-speed motion.

7. Velocity overshoot fix (enabled/disabled)

When enabled: if the IMU-integrated speed exceeds the US-derived speed by more than 2× in the same direction, velocity is immediately snapped to the US value instead of blending gradually. Prevents the tracked position from coasting past the beacon's true location after rapid deceleration.

8. Velocity undershot fix (enabled/disabled)

When enabled: if the US-derived speed exceeds the IMU speed by more than 2×, the real-time low-latency IMU sensor fusion assumes the IMU dead-reckoning has lagged behind (for example, because the gyro-rate gate suppressed acceleration during a fast turn) and immediately snaps velocity to the US-derived value for fast recovery.

9. Drift velocity smooth rate

Smoothing rate (1/s) for the internal drift-correction velocity, which is the inner loop of the second-order drift-decay system. Higher values make the drift correction react more sharply to each US fix; lower values spread the correction impulse more gradually. Typical range: 10–30 /s.

10. Velocity decay rate, Hz

Exponential decay rate (1/s) applied to the IMU velocity when no valid ultrasonic fix has been received for longer than the stale threshold. Prevents unbounded position drift during prolonged US outages by gradually bringing velocity to zero.

11. Ultrasound stale, sec

If no valid ultrasonic fix arrives for this many seconds, the IMU sensor fusion enters stale mode: acceleration integration stops and velocity decays toward zero. Should be set longer than the typical gap between US fixes plus any expected interruptions.

12. Minimum ultrasound quality, %

Ultrasonic fixes with a quality value below this threshold are rejected entirely. Quality (0–100%) is reported by the Marvelmind hardware based on signal strength and measurement consistency. Increasing this threshold reduces noise at the cost of discarding more fixes in difficult environments.

13. US sigma for outlier suppress, m

When an incoming US fix lands this far from the velocity-predicted position, its correction weight drops to 0.5; fixes further away receive progressively less weight. Set this to match the typical noise level of the ultrasonic system in your environment — not the maximum possible jump distance. Typical values: 0.06–0.10 m for slow motion, 0.10–0.15 m for fast motion.

14. US min weight for outlier suppress

Floor on the correction weight applied to any US fix, regardless of how large its residual is. Ensures that even very suspicious fixes contribute a small correction, preventing the IMU sensor fusion from completely ignoring the US track after a large position error.

15. Use US trust weights (enabled/disabled)

Enables the trust-recovery system. After a fix is flagged as an outlier, subsequent fixes are compared against the IMU dead-reckoning prediction rather than the previous US position, making further wrong-track fixes visibly inconsistent. Trust in the US track rebuilds gradually over the following non-outlier fixes. Disabling this applies all fixes with their raw outlier-suppression weights only, without the additional prediction-based blending.

16. US trust ref residual, m

Reference jump distance for the trust-rebuild time calculation. A position jump of exactly this size triggers a rebuild lasting “US trust N base” consecutive valid fixes. Larger jumps scale the rebuild period up (toward N max); smaller jumps scale it down (toward N min).

17. US trust N base

Baseline number of consecutive valid fixes needed to restore full trust after a jump equal to “US trust ref residual”. This count is scaled proportionally for other jump sizes, then clamped to the N min / N max range.

18. US trust N min

Minimum trust-rebuild duration in fixes, regardless of how small the outlier was. Prevents trust from being instantly restored even after very small disruptions.

19. US trust N max

Maximum trust-rebuild duration in fixes, regardless of how large the outlier was. After this many fixes the IMU sensor fusion unconditionally accepts the current US track, treating the position as a genuine relocation rather than a persistent measurement error.

20. US stuck N

Number of consecutive outlier fixes (while trust is already at zero) required to trigger forced convergence. This handles the case where the fused position has diverged so far that every genuine US fix looks like an outlier — a self-reinforcing loop that would otherwise persist indefinitely.

21. US stuck jump scale

Minimum position jump fraction applied per fix when forced convergence is active. Overrides the normally-suppressed (low outlier-weight) jump to close the divergence gap faster than the beacon moves. For example, 0.60 means 60% of the remaining position error is corrected at each fix.

22. US stuck weight floor

Minimum effective weight used for the drift-decay rate when forced convergence is active. Ensures drift correction keeps pace with the larger forced position jumps.

23. Pos error for velocity damp, m

When the fused output is farther than this from the last valid US fix and the velocity is pointing away from that fix (diverging), emergency velocity damping is applied. This breaks the runaway feedback loop where accumulated IMU integration errors push the position ever further from the true location.

24. Velocity damp max rate, Hz

Maximum rate (1/s) for the emergency position-error velocity damping. The actual damping rate ramps linearly from zero at the threshold distance (item 23) up to this maximum. Higher values correct runaway drift faster but may also noticeably reduce speed when the beacon legitimately moves far from its last fix.

25. Accel linear threshold, m/s^2

World-frame linear acceleration above which a soft velocity limiter gradually reduces the integrated velocity. Intended to prevent velocity runaway when very large dynamic accelerations make gravity subtraction unreliable. Set this high enough to leave normal walking or running unaffected.

26. Use velocity accel gate (enabled/disabled)

When enabled, velocity correction at each US fix is reduced in proportion to the current linear acceleration. Intended to prevent the US-derived velocity (which averages position over the fix interval) from pulling down the IMU velocity during rapid acceleration. Currently recommended off — the gyro-rate gate (items 35–37) handles the same cases more accurately.

27. Accel gate threshold (m/s^2)

Acceleration level at which the velocity accel gate begins suppressing velocity correction. At this level the correction weight is halved; at twice this level it reaches zero. Only relevant when “Use velocity accel gate” is enabled.

28. Snap min US speed (m/s)

Minimum US-derived speed required for the overshoot and undershot snap logic (items 7–8) to activate. When two consecutive US fixes show nearly the same position, the derived speed is near zero — without this threshold the snap condition would falsely trigger on any non-zero IMU velocity and zero out a correctly built speed estimate.

29. KP: speed of tilt correction

Proportional gain of the Mahony orientation filter. Controls how quickly the estimated pitch and roll are corrected toward the gravity direction measured by the accelerometer. Higher values react faster to tilt changes but make the orientation more sensitive to vibration and linear acceleration.

30. KI: gyro bias removal rate

Integral gain of the Mahony orientation filter. Slowly corrects the residual gyroscope zero-rate offset that was not removed during startup calibration. Typical value is very small (0.001–0.01) — this term acts over tens of seconds and should not be increased significantly.

31. Yaw minimum displacement

Minimum distance (m) the beacon must travel between two consecutive US fixes before the yaw-nudge correction is attempted. Below this threshold the displacement direction is too short and noisy to serve as a reliable heading reference.

32. Maximum yaw correction, deg

Hard cap on the yaw correction applied in response to a single US fix. Limits how much the estimated heading can be changed by one measurement, protecting against heading jumps from noisy displacement data.

33. Yaw error gain

Fraction of the computed heading error (difference between the US displacement direction and the IMU velocity direction) that is applied as a yaw correction at each fix. Lower values accumulate heading corrections slowly for more stable behavior; higher values react faster to real heading errors.

34. Yaw correction gain for pair

Continuous yaw correction rate (1/s) for the external heading reference provided by the paired beacons. The orientation quaternion is pulled toward this reference at every IMU update step, similar to a magnetometer correction. The effective time constant is approximately 1/gain seconds. Requires a valid paired-beacon heading signal.

35. Use gyro rate for accel gate (enabled/disabled)

Enables suppression of acceleration integration when the beacon rotates too fast for the orientation filter to track accurately. At high angular rates, errors in gravity subtraction produce large spurious linear accelerations in the world frame that corrupt dead-reckoning position. This gate prevents those artifacts from entering the velocity and position integrals.

36. Gyro rate for accel gate

Angular rate threshold (rad/s) above which the acceleration gate switches from full integration to projection mode. In projection mode only the component of acceleration along the current velocity direction is integrated; transverse components (arising from centrifugal effects at the IMU's physical offset from the center of rotation) are discarded. Below this threshold, full integration is used.

37. Gyro rate for accel gate freeze

Angular rate threshold (rad/s) above which acceleration integration is completely frozen. Between setting 36 and this threshold, projection mode is used. Above this threshold, no acceleration is integrated at all until the rotation slows down. This protects against the extreme case where centrifugal acceleration at the IMU's offset from the rotation center is large enough to reverse the estimated velocity within milliseconds.