# Validation and Performance Evaluation of Two Different Inertial Navigation System Design Approaches

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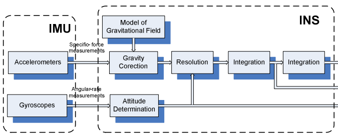
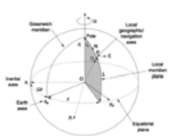
## Abstract

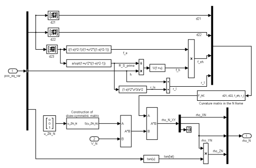
This study is to implement and evaluate two different INS design approaches. Specifically for the classic two-speed digital INS design, the discrete INS models, the high/low speed digital integration algorithms, coning/sculling/scrolling compensations for the low speed calculation in attitude/velocity/high precision positioning determination are implemented in a C programming environment. For the simplified INS design, the single high-speed INS algorithm free of coning/sculling/scrolling compensations is investigated. Moreover by utilising Matlab Simulink's capability to solve the continuous-mode differential equations, instead of using the discrete INS models, the continuous INS models are directly employed in the simplified INS design. The performances of the two developed INS designs are validated and evaluated inside an integrated GPS/INS solutions based on a practical loosely-coupled Kalman filter. Real-time IMU raw measurements logged from the tactic-grade Ring Laser Gyros (RLG)/accelerometers and GPS solutions corresponding to the road testing trajectory is utilised in the validation and evaluation.

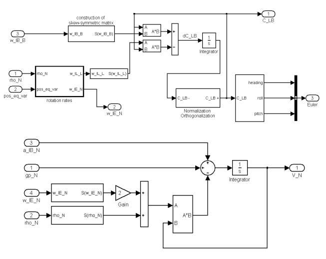

Basic concept of INS



Coordinates Definition

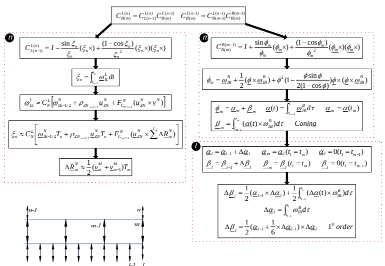


Transport Rate Continuous Mode

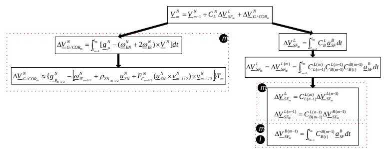


Attitude/ Velocity Determination – Continuous Mode

## Design Methods



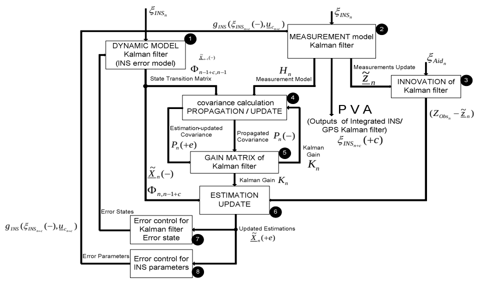
Attitude Determination – Digital Mode



Velocity Determination – Digital Mode

## Research Outlines

- Digital INS Algorithm ( C Programming Based)
- Continuous INS Algorithm ( Simulink Based )
- Integrated Kalman Filter Design
- Real-time Honeywell IMU Data Validation



Kalman Filter

$$A(t)=\begin{cases}\dot{\Psi}^N = -C_B^N\,\delta\underline{\omega}_{IB}^B - \underline{\omega}_{IN}^N \times \Psi^N \\ \delta\dot{\underline{V}}^N = C_B^N\,\delta\underline{a}_{SF}^B - \underline{a}_{SF}^N \times \Psi^N + \delta\underline{g}_{Mdl}^N - (2\underline{\omega}_{IE}^N + \underline{\omega}_{EN}^N)\times\delta\underline{V}^N \\ \delta\dot{\underline{R}}^N = \delta\underline{V}^N - \underline{\omega}_{EN}^N \times \delta\underline{R}^N\end{cases}$$

$$A(t)=\begin{cases}\dot{\Psi}^N = -C_B^N\,\delta\underline{\omega}_{IB}^B \\ \delta\dot{\underline{V}}^N = C_B^N\,\delta\underline{a}_{SF}^B - \underline{a}_{SF}^N \times \Psi^N \\ \delta\dot{\underline{R}}^N = \delta\underline{V}^N\end{cases}$$

$$\Delta\Phi_{\lambda\lambda_m} = \int_{t_{m-1}}^{t_m} A(t)dt$$

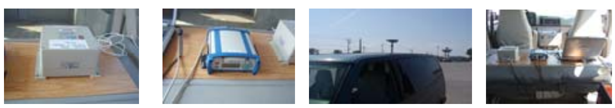
$$\Phi_m = I + \Delta\Phi_{\lambda\lambda_m} + \frac{1}{2}\Delta\Phi_{\lambda\lambda_m}^{\;2}$$

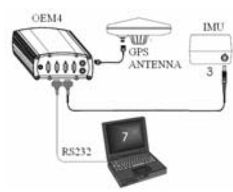
$$\Delta\Phi_{\lambda\lambda_m} = \int_{t_{m-1}}^{t_m} A(t)dt = \begin{cases} A(t_{m-1})\cdot T_m & (1) \\ \frac{1}{2}[A(t_{m-1})+A(t_m)]\cdot T_m & (2)\end{cases}$$

$$T_m = t_m - t_{m-1}$$

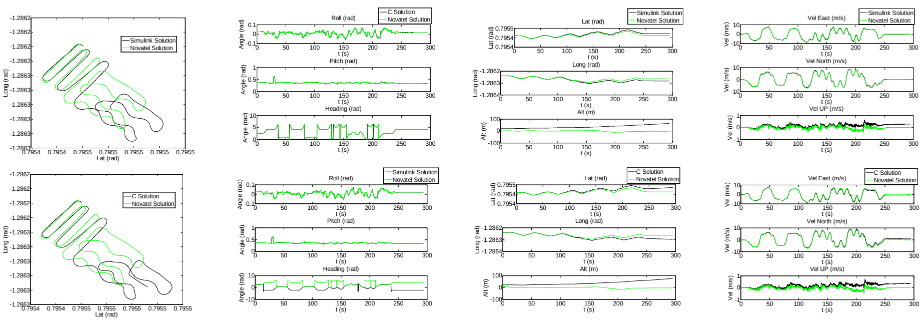
Integration algorithm of INS error equations

## System Validation and Experimental Results

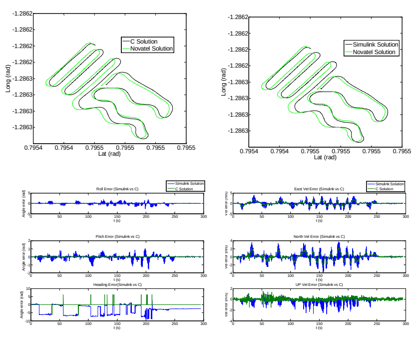


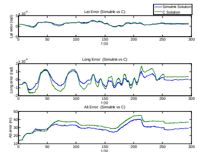



Test Setup



INS stand-alone solution from Simulink and C vs. NovAtel Best Velocity solution





INS/GPS integration solution from Simulink/C vs. NovAtel Best PVA solution

## Conclusion

- Stand-alone INS solutions from C and Simulink approaches are validated
- Both of the approaches reach the same level of precision
- C programming-based stand-alone INS saves 90% of the processing time
- Integrated INS/GPS delivers the improved solutions by estimate/compensate the raw IMU noises

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