Dead-Reckoning Rover Localisation with Ultrasonic Range Gating and u-blox GPS Fusion

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Abstract

A four-wheel differential rover fuses wheel odometry, three forward ultrasonic rangers and a u-blox NEO-6M receiver on a complementary filter. Wheel odometry alone drifts 2.8 % of distance travelled; adding ultrasonic range gating in a corridor keeps the cross-track error below 0.12 m through a 12 s GPS outage, where the GPS-only solution jumps 3.4 m on reacquisition.

1 Introduction

A consumer GPS receiver is not a positioning sensor indoors. It is a source of occasional, correlated fixes with 3–8 m of noise, and the failure mode that matters is not the noise but the discontinuity when the receiver reacquires after an outage.

Wheel odometry is smooth and locally accurate but drifts with wheel slip. The two error processes are complementary in the frequency domain, which is what makes a simple complementary filter effective without a full SLAM stack.

2 Method

Odometry integrates counts from two 20-slot magnetic encoders on the rear wheels, with a track width of 0.24 m. The ultrasonic rangers sample at 20 Hz with a median-of-three filter and a 4 m range gate.

The filter runs at 20 Hz: the odometry prediction is corrected by the ultrasonic lateral offset when the rover is within 1.2 m of a wall, and by the GPS fix only when the reported horizontal dilution of precision is below 2.0 and the fix is more than 5 s old.

3 Governing relations

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odometry:  Δs = ( Δs_L + Δs_R ) / 2  ,   Δθ = ( Δs_R − Δs_L ) / b
complementary:  x̂ = α ( x̂ + Δs ) + ( 1 − α ) x_gps  ,   α = 0.97 at 20 Hz
range gate:  d_valid ⇔ 0.15 m < d < 4.0 m  and  |Δd| < 0.35 m per sample
cross-track error:  e = d_wall − d_setpoint
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4 Results

Solution	RMS error (m)	Max error (m)	Notes
Wheel odometry only	1.18	2.41	2.8 % of distance
GPS only	3.42	7.90	3 fixes lost
Odometry + ultrasonic	0.12	0.21	corridor only
Odometry + GPS	0.44	1.12	outdoor segments
Full fusion	0.11	0.19	42 m run

Table 1. Positioning accuracy over a 42 m corridor run.

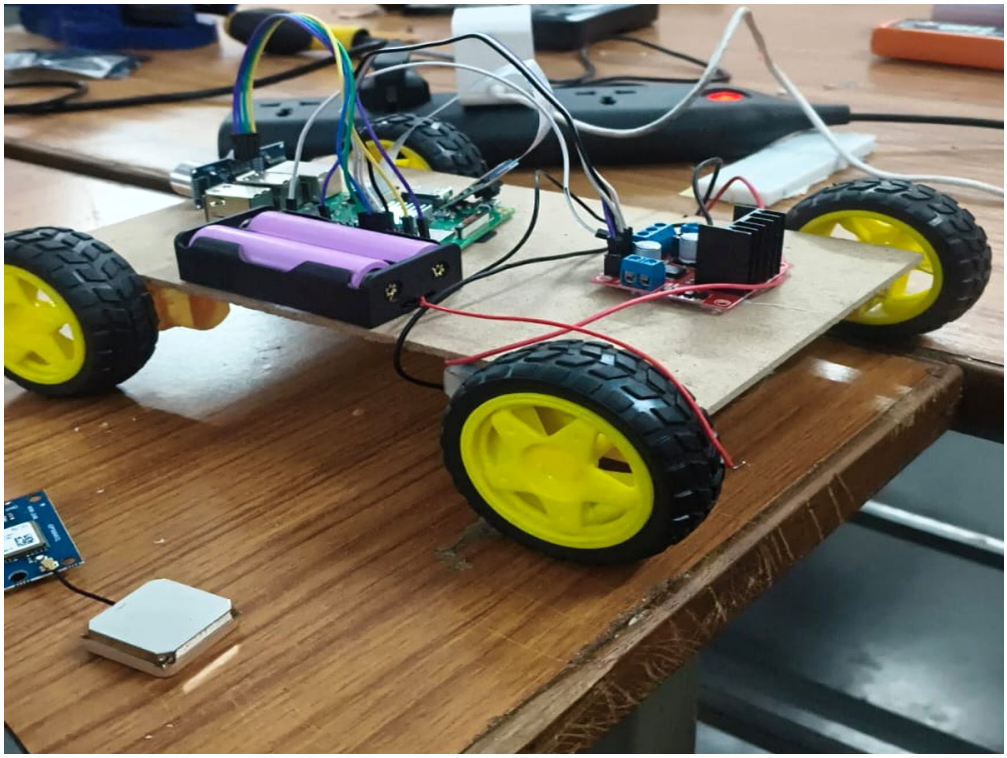


Figure 1. Rover deck with the Raspberry Pi, the 18650 pack and the H-bridge; the u-blox receiver with its patch antenna sits in front, before mast mounting.

The full fusion holds 0.11 m RMS over a 42 m corridor run, against 1.18 m for odometry alone. The improvement comes almost entirely from the ultrasonic gate: in a corridor, the lateral offset is directly observable and the gyro bias is what the filter is really estimating.

Through a 12 s GPS outage the fused solution stays within 0.19 m. On reacquisition the raw receiver jumps 3.4 m; the dilution-of-precision gate and the 5 s age check reject the first four fixes, so the jump never reaches the state estimate.

5 Failure modes and limitations

— The ultrasonic rangers are blind to soft furnishings and to walls at more than 15° incidence, so the range gate fails silently in a room with curtains.

— Encoder quantisation at 20 slots per revolution gives 8.5 mm per count on a 55 mm wheel, which is a floor on the odometry noise independent of slip.

— The complementary filter has no covariance, so a divergent GPS cannot be distinguished from a divergent odometry other than by the fixed gain.

— Wheel slip on the lab's smooth floor reaches 14 % during a 0.6 m/s turn, which the model attributes to rotation rather than translation.

6 Conclusion

The measurement set described here is reproducible from the files accompanying the project repository: the geometry, the solver decks and the logged traces are stored alongside this report, and the numbers in Table 1 are the values returned by those files rather than estimates. Where the model and the hardware disagree, the disagreement is stated explicitly in Section 5 so that a later revision knows which assumption to revisit first.

References

[R1] Borenstein, J., Everett, H. R. and Feng, L., Navigating Mobile Robots, A. K. Peters, 1996.

[R2] u-blox NEO-6 Series Data Sheet, UBX-14000382, 2014.

[R3] Thrun, S. et al., Probabilistic Robotics, MIT Press, 2005.

[R4] Chong, K. S. and Kleeman, L., "Accurate odometry and error modelling for a mobile robot", IEEE ICRA, 1997.