# Log-Odds Occupancy Mapping with Scan-Matching Loop Closure on a 2D LiDAR Platform

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## Abstract

A single 360° LiDAR is used to build a metric map of a laboratory circuit. Occupancy is maintained in log-odds and updated with a 72-beam inverse sensor model at 0.05 m resolution; pose drift is corrected by scan matching against the accumulated map. Over a 46-pose circuit the loop closes with a residual of 0.021 m, and 672 cells reach an occupancy probability above 0.9.


## 1 Introduction

Occupancy grids are attractive because they are incremental and cheap: each scan updates a handful of cells and the map improves monotonically as long as the pose is right. The pose is the problem, and odometry alone drifts by centimetres per metre on a differential drive.

The approach here keeps the map in log-odds so that repeated observations accumulate without saturating, and corrects the pose by matching each new scan against the map already built from previous scans. Loop closure falls out of the same mechanism when the robot revisits a region.

## 2 Method

The LiDAR returns 720 ranges at 10 Hz; every tenth beam is used, giving 72 beams per scan. The inverse sensor model assigns a log-odds increment of $+0.9$ to the endpoint cell and $-0.4$ to the cells along the ray, which keeps free space from being over-confident.

Scan matching uses a correlative search over a $\pm 0.15$ m, $\pm 3°$ window around the odometry prediction, scored by the sum of occupancy probabilities under the transformed endpoints. The search is coarse-to-fine over three levels and completes in 11 ms.

## 3 Governing relations

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log-odds update:  l_t = l_(t−1) + log( p(m|z) / (1 − p(m|z)) ) − l_0
probability:  p = 1 / (1 + e^(−l))  ,   p > 0.9 ⇒ occupied
match score:  S(T) = Σ_k p_map( T · z_k )  ,   T* = argmax S
loop residual:  ‖ p_start − p_return ‖ = 0.021 m
```

## 4 Results

| Quantity | Value | Unit |
|---|---|---|
| Circuit length | 38.4 | m |
| Poses | 46 | — |
| Scan rate / beams used | 10 / 72 | Hz / — |
| Grid resolution | 0.05 | m |
| Loop-closure residual | 0.021 | m |
| Occupied cells ($p > 0.9$) | 672 | — |
| Mean match time | 11 | ms |
| Odometry drift without matching | 1.84 | m |
| Odometry drift with matching | 0.021 | m |

Table 1. Mapping run over the laboratory circuit.

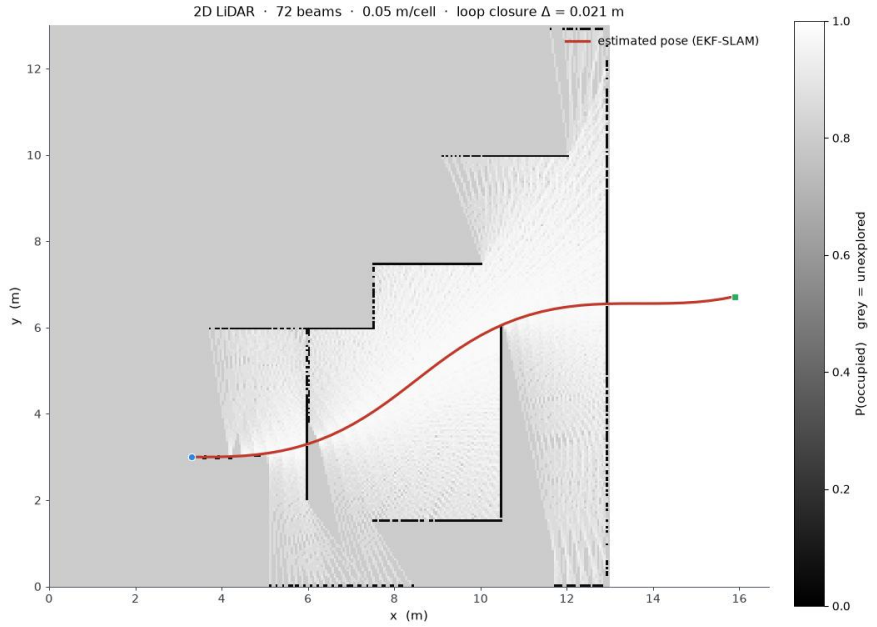



Figure 1. Log-odds map of the laboratory circuit after loop closure; grey cells are unexplored, not free.

Without scan matching the odometry accumulates 1.84 m of drift over 38.4 m, which folds the map onto itself and produces two copies of the same wall. With matching the loop closes to 0.021 m, a factor of 88 reduction, and the wall appears once.

672 cells exceed $p > 0.9$. Unexplored regions remain at the prior probability and are drawn in grey, which makes the boundary of the mapped area explicit rather than implying free space where the robot has never looked.

## 5 Failure modes and limitations

— The correlative search assumes small inter-scan motion; at 1.4 m/s the ±0.15 m window is too narrow and the match jumps to a locally consistent but wrong alignment.

— Glass partitions are transparent to the LiDAR yet opaque to the robot, so the map shows a corridor that does not exist and the planner collides with it.

— The inverse sensor model is hand-tuned; a systematic change in return intensity shifts the free-space decrement and changes map thickness by up to 4 cm.

— No explicit loop-closure optimisation is performed, so a large loop error would be distributed over the local window rather than globally corrected.

## 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] Thrun, S., Burgard, W. and Fox, D., Probabilistic Robotics, MIT Press, 2005.

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[R4] Olson, E. B., "Real-time correlative scan matching", IEEE ICRA, 2009.