Comparison of Kalman versus Interval based loop detection problem

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Introduction

Detecting loops in a mobile robot trajectory is a problem that can be resolved by two main approaches: using exteroceptive measurement and comparing the environment to a knowledge database or using proprioceptive measurement using a method developed in previous work that use interval analysis [1]. This talk proposes to compare Kalman versus the interval approach applied to loop detection with proprioceptive measurement only.

Kalman based method

A Kalman filter could be implemented without exteroceptive measurement for localization problem (dead reckoning). In this case, this Kalman predictor integrates proprioceptive data and is able to estimate the position of the robot with an error given by a covariance matrix.

When the evolution of a robot is described by classical state equation:

$$x_{k+1} = A_k.x_k + u_k, \tag{1}$$

where u_k represent inputs, A_k the state matrix and x_k the state of the robot, a Kalman predictor can be applied to determine it's uncertain

state $\hat{x}$:

$$\begin{cases} \hat{x}_{k+1} = A_k.\hat{x}_k + u_k \\ \Gamma_{k+1} = A_k.\Gamma_k.A_k^T + \Gamma_\alpha \end{cases}, \tag{2}$$

where Γ_{k+1} is the covariance matrix representing the uncertainty and Γ_α the covariance associated with a normally distributed noise.

In order to detect loops with a Kalman filter, we propose to compute distances between two estimated positions. Since [3]:

$$\hat{x}_k = P_k^0 \hat{x}_0 + \sum_{i=0}^{k-1} P_{k+1}^i u_i \tag{3}$$

$$\Gamma_k = P_k^0 \Gamma_0 \left(P_k^0\right)^T + \sum_{i=1}^{k} P_k^i \Gamma_\alpha \left(P_k^i\right)^T \tag{4}$$

where transition matrices P_k^i are defined by

$$\begin{aligned} P_k^i &= A_{k-1}A_{k-2}...A_i.I, \\ P_k^k &= I, \\ P_k^i &= P_k^l P_l^i, \\ P_k^i &= P_k^0 \left(P_i^0\right)^{-1}, \end{aligned}$$

we can derive an explicit form of those positions. In this context, loops are detected by pairs of timesteps k_1, k_2 which satisfies $\hat{x}_{k1} = \hat{x}_{k2}$ over position coordinates.

Main results

This talk will present results of the Kalman approach to resolve loop detection problem with proprioceptive measurement only and compare them with the interval based method. We will apply the Kalman method to an experiment done by the underwater minehunter Redermor from GESMA which have been already treated with the interval approach. Figure **??** represent results as *t-planes* given by both methods.

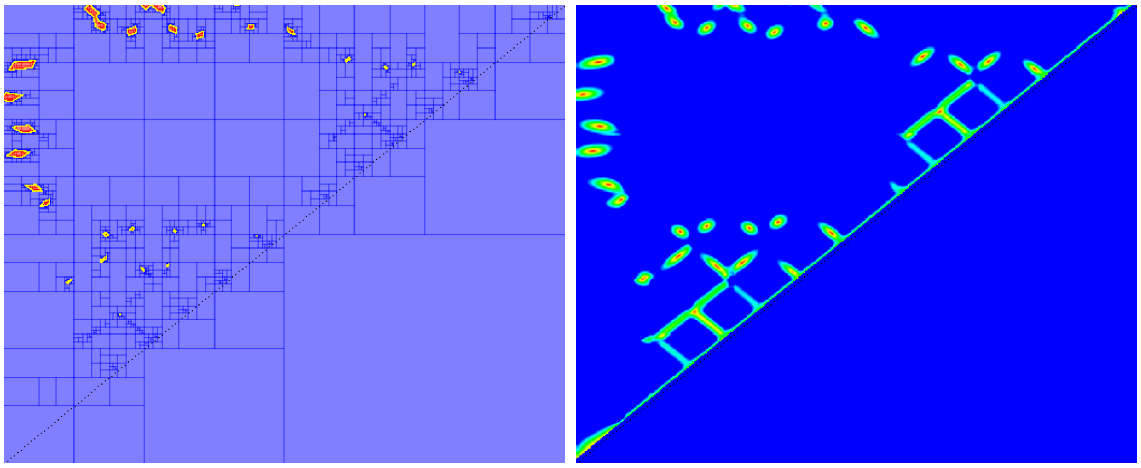

Figure 1: t-plane results of loop detection problem solved by: interval method(left), Kalman method(right).

References

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