ekf_localizer validation results

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Experiment

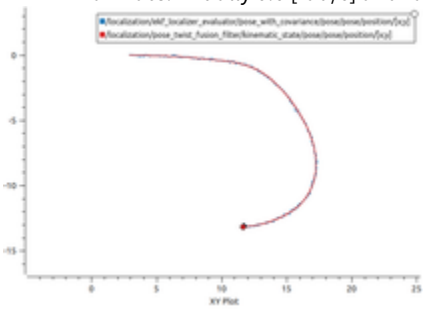
Criterion

- Estimation error: RMSE (for xy only)
- Covariance size: mean of long radius size (1-sigma covariance)
- Calculation time: the time it took to the update step

Overview of toy data

Generate ground truth velocity and yaw rate at the rate of 50 Hz, and calculated a ground truth trajectory

- Motion model is the same one used in ekf_localizer
- Velocity: 1 [m/s] constant
- Yaw rate: Initially 0.0 [rad/s] and random walks at 0.2[rad/s/s]



Experiment 1: Multiple poses

Here, “calc time” is a calculation time of measurementUpdatePose(); at each step in ekf_localizer

	ekf smoothing	extended state step	pose input 1	pose input 2	pose input 3	twist input 1	results
exp_00 Original EKF (reference)	N/A	50	rate: 10.0 delay: 0.0 stddev_x: 0.05 stddev_yaw: 0.025			rate: 50.0 delay: 0.0 stddev_x: 0.01 stddev_yaw: 0.005	RMSE: 0.023[m] Stddev: 0.0346 [m] Calc time (mean): 0.65 [ms] Calc time (max): 3.32 [ms]
exp_01 Normal (Ours)	5	50	rate: 10.0 delay: 0.0 stddev_x: 0.05 stddev_yaw: 0.025			rate: 50.0 delay: 0.0 stddev_x: 0.01 stddev_yaw: 0.005	RMSE: 0.024[m] Stddev: 0.0354 [m] Calc time (mean): 0.66 [ms] Calc time (max): 6.46 [ms]

exp_02 Time delay	5	50	rate: 10.0 delay: **0.5** stddev_x: 0.05 stddev_yaw: 0.025			rate: 50.0 delay: 0.0 stddev_x: 0.01 stddev_yaw: 0.005	RMSE: 0.027[m] Stddev: 0.0409 [m] Calc time (mean): 0.65 [ms] Calc time (max): 4.18 [ms]
exp_03 Multiple sensors	5	50	rate: 10.0 delay: 0.0 stddev_x: 0.05 stddev_yaw: 0.025	rate: 20.0 delay: 0.0 stddev_x: 0.1 stddev_yaw: 100000.0		rate: 50.0 delay: 0.0 stddev_x: 0.01 stddev_yaw: 0.005	RMSE: 0.024[m] Stddev: 0.0322 [m] Calc time (mean): 1.34 [ms] Calc time (max): 9.80 [ms]
exp_04 Multiple sensors, time delay	5	50	rate: 10.0 delay: **0.5** stddev_x: 0.05 stddev_yaw: 0.025	rate: 20.0 delay: **0.9** stddev_x: 0.1 stddev_yaw: 100000.0		rate: 50.0 delay: 0.0 stddev_x: 0.01 stddev_yaw: 0.005	RMSE: 0.030[m] Stddev: 0.0499 [m] Calc time (mean): 1.36 [ms] Calc time (max): 9.89 [ms]
exp_05 Smoothing	**20**	50	rate: 10.0 delay: 0.0 stddev_x: 0.05 stddev_yaw: 0.025			rate: 50.0 delay: 0.0 stddev_x: 0.01 stddev_yaw: 0.005	RMSE: 0.022[m] Stddev: 0.0326 [m] Calc time (mean): 2.40 [ms] Calc time (max): 16.2 [ms]
exp_06 Multiple sensors, smoothing	**20**	50	rate: 10.0 delay: 0.0 stddev_x: 0.05 stddev_yaw: 0.025	rate: 20.0 delay: 0.0 stddev_x: 0.1 stddev_yaw: 100000.0		rate: 50.0 delay: 0.0 stddev_x: 0.01 stddev_yaw: 0.005	RMSE: 0.024[m] Stddev: 0.0364 [m] Calc time (mean): 3.91 [ms] Calc time (max): 22.1 [ms]
exp_07 Extended state step	5	**200**	rate: 10.0 delay: 0.0 stddev_x: 0.05 stddev_yaw: 0.025			rate: 50.0 delay: 0.0 stddev_x: 0.01 stddev_yaw: 0.005	RMSE: 0.022[m] Stddev: 0.0287 [m] Calc time (mean): 9.21 [ms] Calc time (max): 24.1 [ms]
exp_08 Extended state step	5	**200**	rate: 10.0 delay: **3.0** stddev_x: 0.05 stddev_yaw: 0.025			rate: 50.0 delay: 0.0 stddev_x: 0.01 stddev_yaw: 0.005	RMSE: 0.057[m] Stddev: 0.0742 [m] Calc time (mean): 9.11 [ms] Calc time (max): 30.4 [ms]
exp_09 A lot	5	**200**	rate: 10.0 delay: **3.14** stddev_x: 0.05 stddev_yaw: 0.025	rate: 20.0 delay: **2.5** stddev_x: 0.1 stddev_yaw: 100000.0	rate: 5.0 delay: **0.3** stddev_x: 0.1 stddev_yaw: 0.05	rate: 50.0 delay: 0.0 stddev_x: 0.01 stddev_yaw: 0.005	RMSE: 0.038[m] Stddev: 0.0626 [m] Calc time (mean): 16.5 [ms] Calc time (max): 32.8 [ms]

Experiment 2: Multiple pose & twist sensors

Here, “calc time” is a calculation time of measurementUpdatePose(); and measurementUpdateTwist(); at each step in ekf_localizer

	ekf smoothing	extended state step	pose input 1	pose input 2	pose input 3	twist input 1	twist input 2	results

exp_00 Original EKF (reference)	N/A	50	rate: 10.0 delay: 0.0 stddev_x: 0.05 stddev_yaw: 0.025			rate: 25.0 delay: 0.0 stddev_x: 0.1 stddev_yaw: 0.01		RMSE: 0.044[m] Stddev: 0.0663[m] Calc time (mean): 0.619 [ms] Calc time (max): 3.83 [ms]
exp_11 Normal (Ours)	5	50	rate: 10.0 delay: 0.0 stddev_x: 0.05 stddev_yaw: 0.025			rate: 25.0 delay: 0.0 stddev_x: 0.1 stddev_yaw: 0.01		RMSE: 0.044[m] Stddev: 0.0693[m] Calc time (mean): 0.74 [ms] Calc time (max): 5.09 [ms]
exp_12 Multiple sensors	5	50	rate: 10.0 delay: 0.0 stddev_x: 0.05 stddev_yaw: 0.025			rate: 25.0 delay: 0.0 stddev_x: 0.1 stddev_yaw: 0.01	rate: 5.0 delay: 0.0 stddev_x: 0.01 stddev_yaw: 10000.0	RMSE: 0.044[m] Stddev: 0.0694 [m] Calc time (mean): 0.68 [ms] Calc time (max): 4.80 [ms]
exp_13 Multiple sensors	5	50	rate: 10.0 delay: 0.0 stddev_x: 0.05 stddev_yaw: 0.025	rate: 20.0 delay: 0.0 stddev_x: 0.1 stddev_yaw: 100000.0	rate: 5.0 delay: 0.0 stddev_x: 0.1 stddev_yaw: 0.05	rate: 25.0 delay: 0.0 stddev_x: 0.1 stddev_yaw: 0.01	rate: 5.0 delay: 0.0 stddev_x: 0.01 stddev_yaw: 10000.0	RMSE: 0.056[m] Stddev: 0.0858 [m] Calc time (mean): 1.32 [ms] Calc time (max): 7.73 [ms]

Results

Original implementation VS the proposed implementation

Overall, the performance is quite similar (see exp_00 vs exp_01, or exp_10 vs exp_11)

The effect of time delay

When the time delay of the sensors is below 1[s], we cannot observe significant degradation in both calculation time and estimation error.

When the time delay is around 3[s], estimation error increases by about 75%.

Related to this, increasing extended_state_step significantly increases the calculation time.

The effect of multiple sensors

The calculation time increases when multiple sensor inputs are available.

We cannot observe a significant change in the estimation error.

The effect of smoothing steps

The calculation time appears to increase linearly when increasing smoothing steps.

We cannot observe a significant change in the estimation error.