2.11 An Outlier-Robust and Efficient Bayesian Filter and Smoother

Jonas Neuhöfer, Jörg Reichardt | Continental AG

KI WISSEN
Automotive AI Powered by Knowledge

Trajectory Prediction and Motion Planning

Motivation

When investigating various prediction tasks in the automotive context, we noticed that even in heavily post-processed datasets, *outliers* abounded [1].

Outliers

Due to inherent instabilities of the processes observing other traffic participants, some of the provided observations deviate significantly from the general trend.

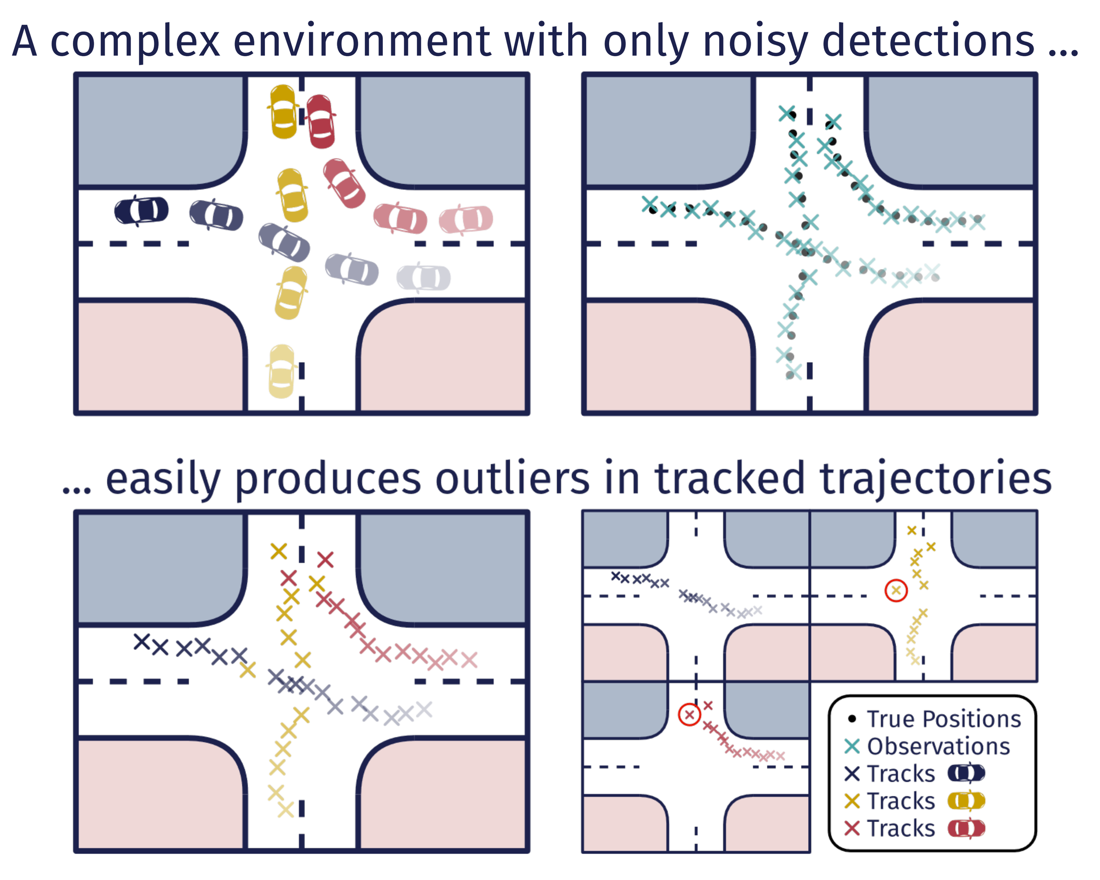

Figure 1: An example of how tracking multiple targets simultaneously from detected observations can result in outliers in the computed tracks (© Continental AG)

Effect

Since predictions must extrapolate from recent observations, the quality and reliability of observations have a substantial impact on prediction performance.

Objective

Infer a realistic trajectory of the targets from these outlier-afflicted observations, including relevant information such as the target's velocities and accelerations.

Problems With Existing Methods in Use

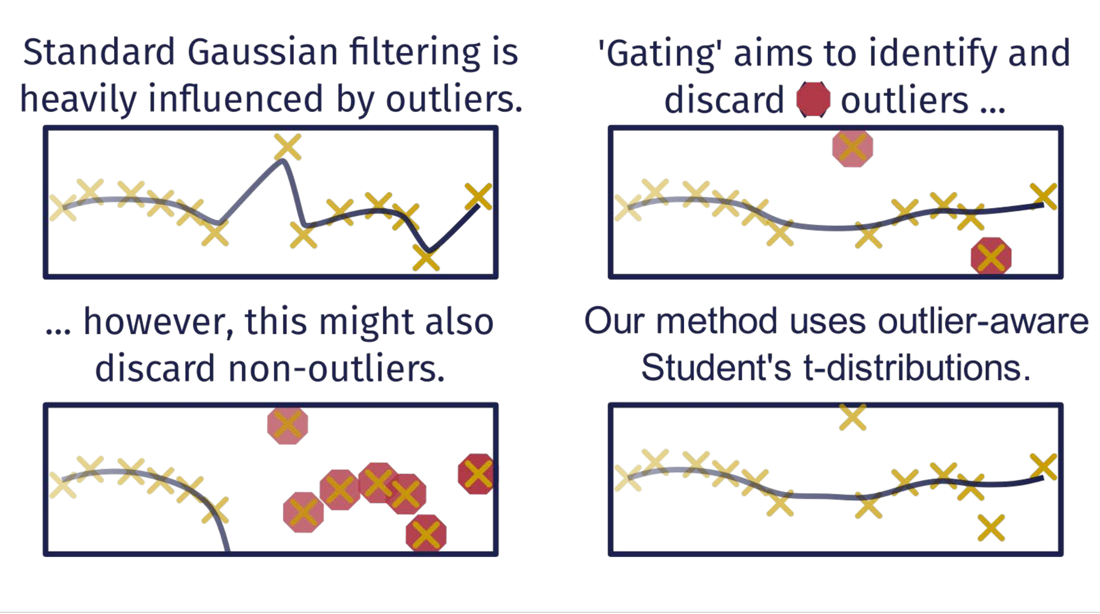

Figure 2: Filtering based on Gaussian distributions and Gating does not reliably produce realistic trajectories (© Continental AG)

Our Proposed Method

We aim to preserve the advantages of existing Gaussian methods in efficiency, interpretability and adaptability to non-linear processes.
We replace the Gaussian assumptions with outlier-aware Student's t-assumptions, identify fallacies in previous works with this approach, remedy these, and provide analytical formulations for our outlier robust methods.

Student's t-Distribution

The Student's t-distribution results from a Gaussian distribution with a random variance. As such, outliers are explained by instances of very high variances. Further, the invariance under affine transformations and conditioning is inherited from Gaussian distributions.

Key Contributions

- We propose a method to approximate joint Student's t-distributions *locally*, motivated by this equality of densities:

Student's t-density evaluated at x | *hyperparameter for frequency of outliers* | *dimensions of x and y* | *mean and (quasi) covariance*

$$t_\nu(x|\mu_1,\Sigma_1)\cdot t_{\nu+m}(y|\mu_2,\Sigma_2)\cdot t_{\nu+m+n}(z|\mu_3,\Sigma_3) = t_\nu\left(\begin{bmatrix}x\\y\\z\end{bmatrix}\middle|\begin{bmatrix}\mu_1\\\mu_2\\\mu_3\end{bmatrix},\begin{bmatrix}\Sigma_1 & 0 & 0\\0 & a(x)\Sigma_2 & 0\\0 & 0 & a(x)b(y)\Sigma_3\end{bmatrix}\right)$$

$$a(x) = \frac{\nu+m}{\nu+(x-\mu_1)^T\Sigma_1^{-1}(x-\mu_1)},\quad b(y) = \frac{\nu+m+n}{\nu+m+(y-\mu_2)^T\Sigma_2^{-1}(y-\mu_2)}$$

- We propose a method to estimate $a(x)$ and $b(y)$ when (x, y, z) are unknown,
- From this method, we derive outlier-robust filter and smoother,
- We compare our filter to state-of-the-art analytical outlier robust filters.

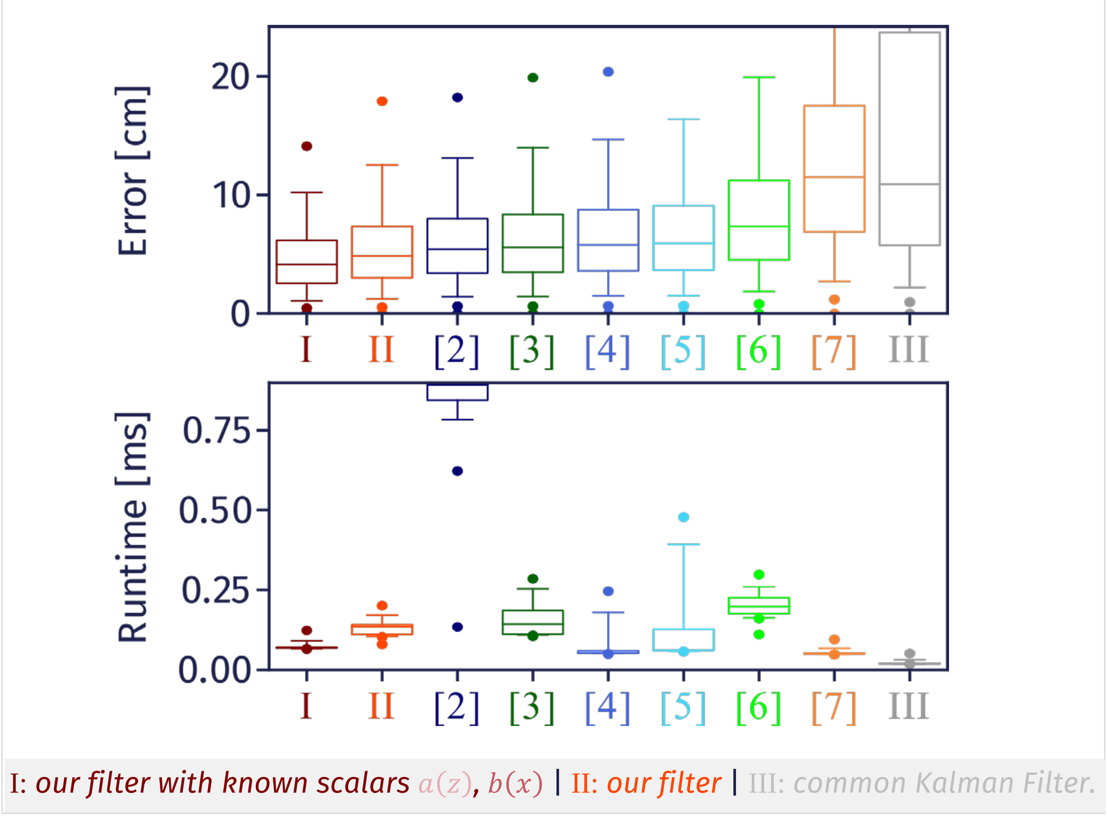

Figure 3: Comparison with comparable filters on challenging simulated tracking tasks. (© Continental AG)

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Partners

External partners

For more information contact:

jonas.neuhoefer@continental.com
joerg.reichardt@continental.com

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