

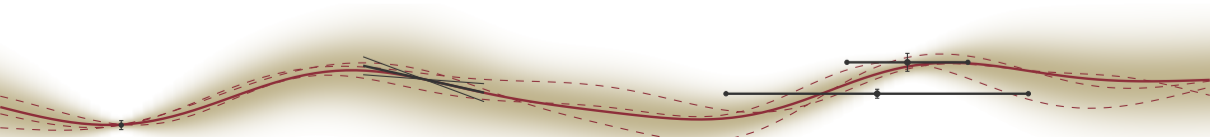
Fenrir: Physics-Enhanced Regression in Initial Value Problems

Filip Tronarp, Nathanael Bosch, and Philipp Hennig

EBERHARD KARLS
UNIVERSITÄT
TÜBINGEN



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Latent initial value problem:

$$\varphi_{\theta}(t) = y_0(\theta) + \int_0^t f_{\theta}(\tau, \varphi_{\theta}(\tau)) \, d\tau, \quad (1a)$$

$$u(t) = H^T \varphi_{\theta}(t) + v(t), \quad t \in \mathbb{T}_D \quad (1b)$$

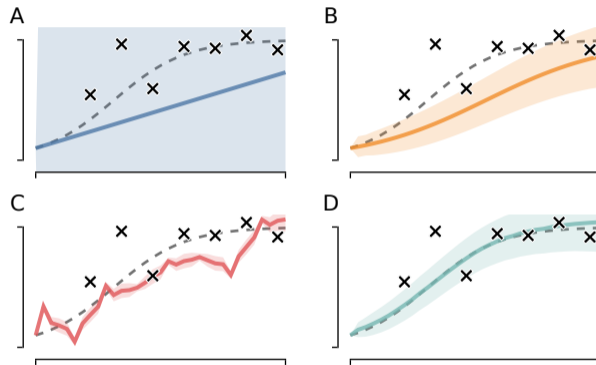
Likelihood:

$$\mathcal{L}_D(R_{\theta}, y) = \prod_{t \in \mathbb{T}_D} \mathcal{N}(u(t); H^T y(t), R_{\theta}), \quad (2a)$$

$$\mathcal{M}(\theta) = \mathcal{L}_D(R_{\theta}, \varphi_{\theta}). \quad (2b)$$

Maximum likelihood:

$$\hat{\theta} = \arg \max_{\theta \in \Theta} \mathcal{M}(\theta). \quad (3)$$



$$\widehat{\mathcal{M}}_N(\theta, \kappa) = \int \mathcal{L}_D(R_\theta, y) \widehat{\delta}_N(y | \theta, \kappa) dy, \text{ where } \widehat{\delta}_N(y | \theta, \kappa) \approx \delta(y - \varphi_\theta).$$

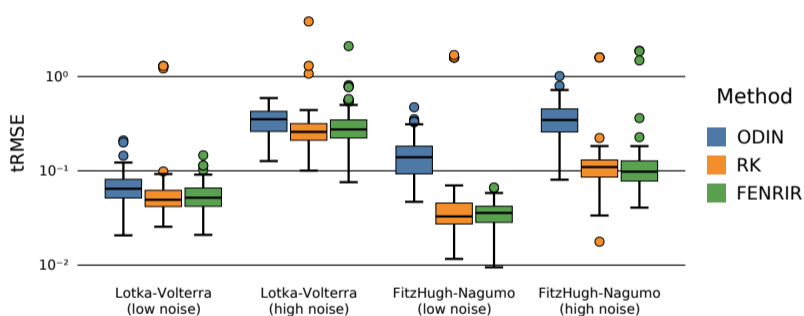
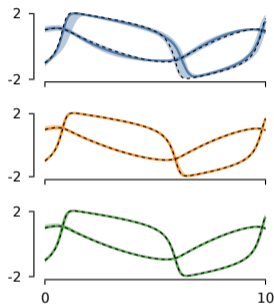


Figure: Left: reconstruction of one trajectory. Right: Reconstruction errors for a Monte-Carlo trial of 100 trajectories.

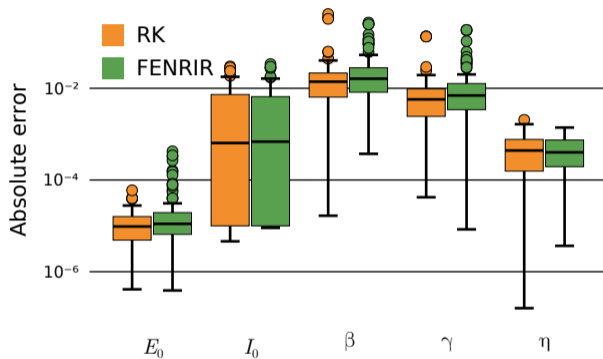
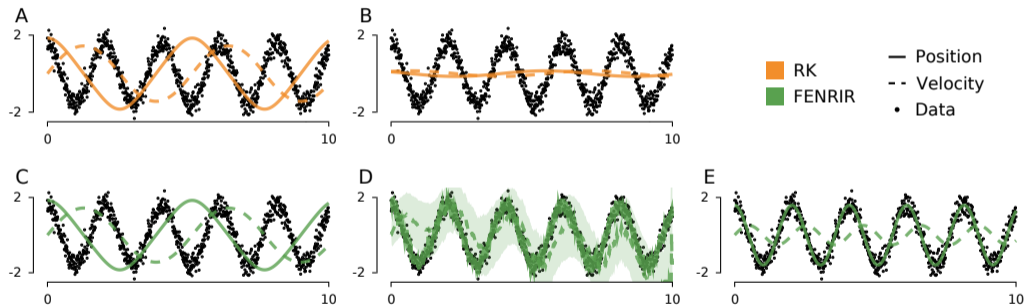


Figure: Parameter errors in a Monte-Carlo trial of the SEIR model.

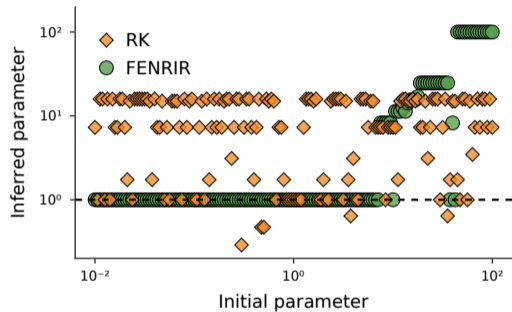
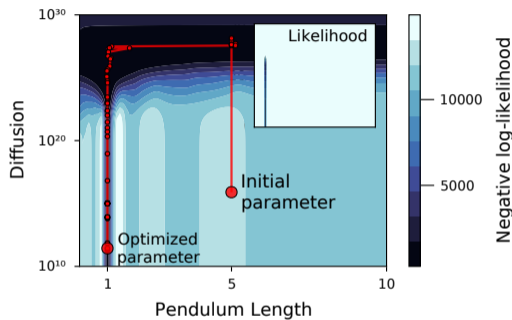
Experiments: Fast oscillations

From initial guess to final estimate



Experiments: Fast oscillations

What is going on?



Want to get in touch?

filip.tronarp@uni-tuebingen.de

nathanael.bosch@uni-tuebingen.de