BAYESIAN CURVE RECONSTRUCTION FROM NOISY STREAMS IN JULIA

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ABSTRACT

Parametric curve reconstruction from partial noisy data is useful for monitoring repetitive trajectories in industrial process state spaces. We iteratively estimate the parameters of a Bayesian model by recursive least squares fitting using LsqFit.jl, integrate them through time updating robust statistics by OnlineStats.jl, represent the results by Makie.jl, and test the procedure on simulated 3D trajectories.

MOTIVATION

The problem: industrial processes are typically well controlled --- state space trajectories are repetitive, except for expected variations due to controlled factors and some noise.

When faults occur, instead, trajectories drift, diverging from the ones observed in the past. In this sense, the reconstruction in near-real time of the trajectories of e.g. pressures and temperatures in a distillation tower, or of a laser beam working on a manufactured item, can be valuable for e.g. security monitoring, quality assurance, control.

The problem: observability is limited to low resolution temporal sections of the (possibly high dimensional) trajectories.

BACKGROUND

Idea: Whenever trajectories are sampled densely in time, we can use model inversion (by e.g. recursive least squares) and online updates to accumulate knowledge on processes during many process instances (e.g. cycles) at many time series points in terms of robust statistics of the estimated model parameters.

We can then detect and isolate fault conditions early, in a predictive maintenance scheme operating at the micro-level (how much time till failure?) and intra-cycle (is the current process instance currently diverging?) rather than per process instance (how many cycles till failure?).

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RESULTS AND DISCUSSION

We built methods for rapid reconstruction from partial noisy data of curves from parametric families. The inversion operates in streaming mode, in the sense that it works by maintaining and updating a snapshot of the acquired data representation and that is only allowed a limited number of views to the data stream which is not Random Access.

The inherent uncertainty is treated by considering a Bayesian inversion framework.

Specific attention is devoted to the exploitation of the conditional independence structure of the problem for the derivation of a concurrent problem definition that lends itself to its integration in a visualization component built on OpenGL.

The produced implementation is generic with respect to the family of curves supported.

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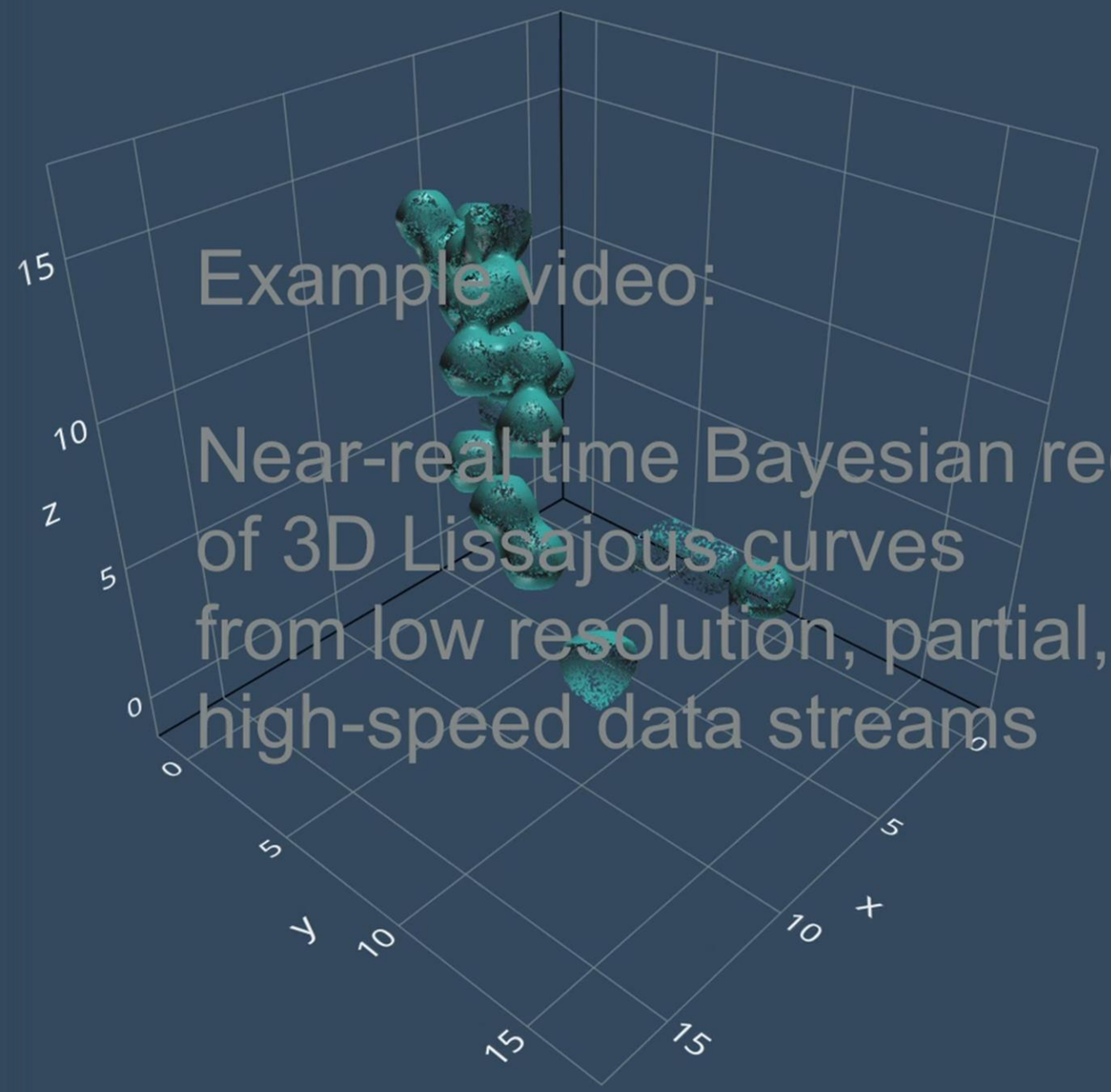
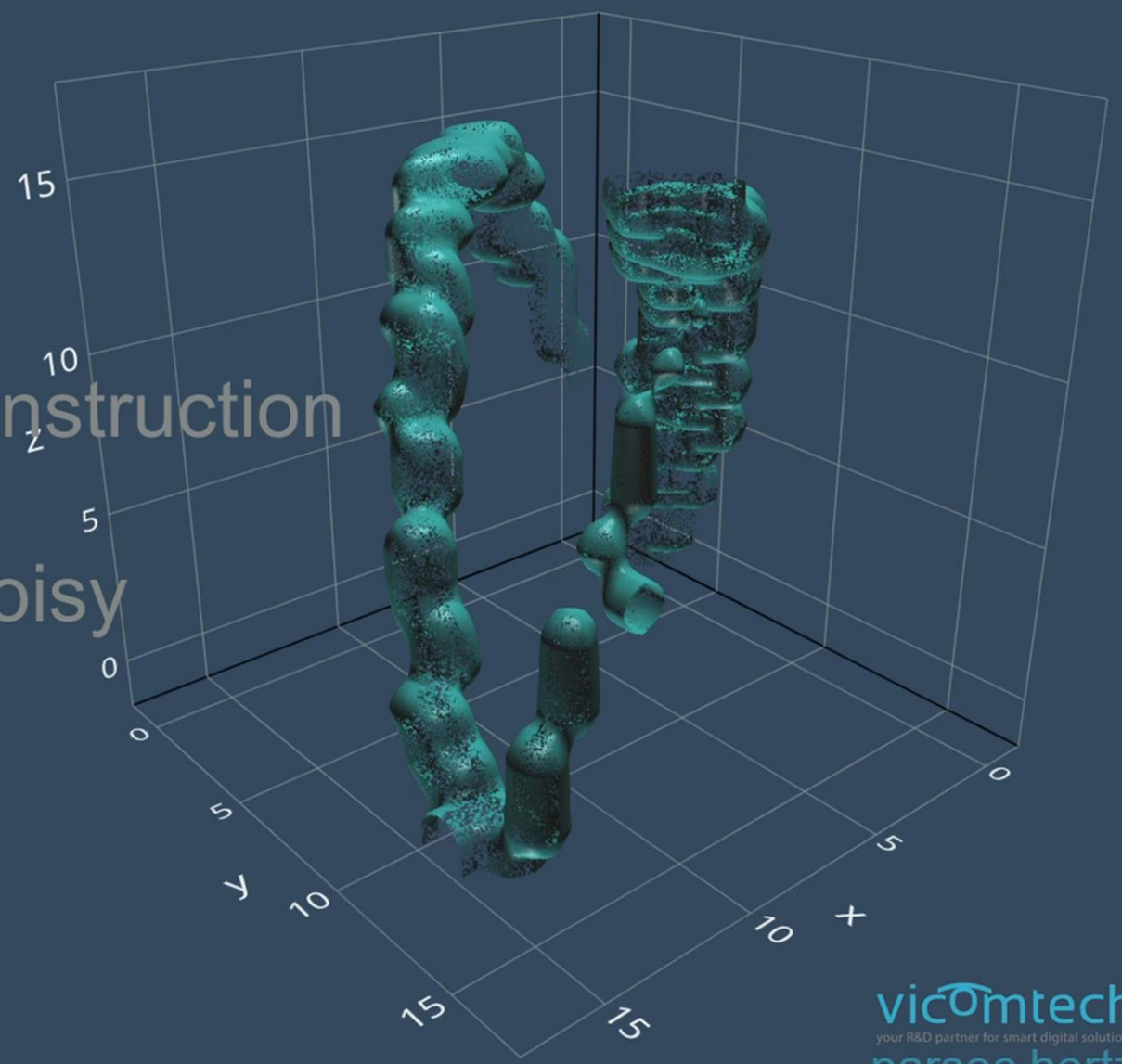
RESULTS AND DISCUSSION

Example video:

Near-real time Bayesian reconstruction of 3D Lissajous curves from low resolution, partial, noisy high-speed data streams





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CONCLUSION

The high speed online updating of robust statistics helps in the reconstruction of N-D trajectories from frequent noisy observations of small temporal sections.

Recursive Least Squares can then be regularized by Bayesian priors.

This is particularly important for the monitoring of processes in e.g. petrochemical and manufacturing industries for security, quality assurance, control.

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