HAMPEL'S LMS IN THE ANALYSIS OF ONLINE MONITORING DATA

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Abstract

We present procedures for online signal extraction from intensive care data. These filtering methods use high-breakdown linear regression methods in moving time windows. In particular, we concentrate on the performance of *Least Median of Squares* (short: LMS) regression in this context. Comparing the LMS to other robust regression techniques, we discuss its merits for preserving clinically relevant patterns such as trends, abrupt shifts and extremes and for the removal of irrelevant spikes or outliers.

Extended Abstract

Proper extraction and interpretation of information contained in multivariate time series measured at intensive care units is a complex and challenging endeavour. Our objective is to abstract the information that are contained in the data and use the output as basis for new, improved alarm systems.

Currently, alarm systems used for monitoring in intensive care record physiological variables such as heart rate or blood pressure at high frequency and compare the measurements to thresholds set by the medical staff. These automatic alarm systems produce many false alarms due to measurement artifacts, patient movements, or transient fluctuations around the chosen alarm limit.

The monitored physiologic time series exhibit trends, abrupt level changes and large spikes (outliers) as well as periods of relative stability. The true values are overlaid with a high level of noise and many artifacts due to physiologic as well as technical causes. Also, strong dynamic dependencies can occur between the variables. On that account, constructing alarm rules based on the true underlying signal, i.e., on a noise-free and artifact-free time series, offers a possibility to improve current alarm systems noticeably.

In this paper, we present methods for robust online signal extraction and discuss their merits for preserving clinically relevant patterns such as trends, abrupt shifts and extremes and for the removal of irrelevant spikes or outliers. Our approach applies linear regression techniques with a high breakdown point to moving time windows (Davies, Fried and Gather, 2004; Gather, Schettlinger and Fried, 2006).

One of the first attempts to robustifying the traditional least squares approach for regression goes back to Hampel (1975) who proposed to use the median of the squared

residuals instead of the sum in the objective function. Here, we compare time series filters based on *Least Median of Squares* (short: LMS) regression to further robust regression filters and discuss its merits for application to intensive care time series. In particular, we regard the ability to preserve clinically relevant patterns such as trends, abrupt shifts and extremes and the ability to remove irrelevant spikes or outliers.

Increased computational power and fast algorithms allow for applying such robust regression filters even in real time (Edelsbrunner and Souvaine, 1990; Bernholt and Fried, 2003; Bernholt, 2005).

Simply generalising univariate robust regression methods to the multivariate case does not result in affine equivariant procedures: For multivariate signal extraction efficiency is lost if the error terms of the variables are highly correlated (Lanius, 2005). On the other hand, multivariate affine equivariant regression methods with high breakdown usually assume that the data are in general position. However, for intensive care data this is often not the case since the measurements are recorded on a discrete scale.

We discuss procedures for univariate and multivariate signal extraction which are fast, efficient and robust, and can be used for discretely measured data with low variability as well as in situations with many outliers.

References

[1] Bernholt Th. (2005). Computing the Least Median of Squares Estimator in Time $O(n^d)$. *Proc. ICCSA 2005, LNCS*. Vol. **3480**, pp. 697-706.

[2] Bernholt Th., Fried R. (2003). Computing the Update of the Repeated Median Regression Line in Linear Time. *Inf. Process. Lett.*. Vol. **88** (1), pp. 111-117.

[3] Davies P.L., Fried R., Gather U. (2004). Robust Signal Extraction for On-line Monitoring Data. *J. Stat. Plann. Inference*. Vol. **122** (1-2), pp. 65-78.

[4] Edelsbrunner H., Souvaine D.L. (1990). Computing Least Median of Squares Regression Lines and Guided Topological Sweep. *JASA*. Vol. **85**, pp. 115-119.

[5] Gather U., Schettlinger K., Fried R. (2006). Online Signal Extraction by Robust Linear Regression. *Comput. Statistics*. Vol. **21** (1), pp. 33-52.

[6] Hampel F.R. (1975). Beyond Location Parameters: Robust Concepts and Methods. *Bulletin of the International Statistical Institute*. Vol. **46**, pp. 375-382.

[7] Lanius V. (2005). *Statistische Extraktion relevanter Information aus multivariaten Online-Monitoring-Daten der Intesivmedizin*. Dissertation, University of Dortmund, Germany.