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Analysis of Freeway Traffic Flow by Extreme Value Statistics

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We perform a statistical analysis of car traffic flow. Car traffic is a complex spatiotemporal nonlinear dynamical process. By regarding the occurence of jams as extreme events, we can analyze freeway traffic flow by means of extreme value statistics.

Our traffic data set comes from German freeways around Cologne, called the "Kölner Ring". The measured observables are velocity, flux and density, averaged per minute.

In a few words the Fisher-Tippet theorem of extreme value statistics says, that if a suitably normalized sequence of maxima of a i.i.d. random variable converges, the limit will be a member of the *generalized extreme value* (GEV) family of distributions.

$$G(z) = exp\Big(- \Big\{ 1 + \xi \Big(\frac{z-\mu}{\sigma} \Big) \Big\}^{-1/\xi} \Big), \qquad z \in \mathbb{R} \tag{1}$$

The real parameters μ and σ correspond, respectively, to location and scale, and the parameter ξ determines the shape of the distribution. For $\xi = 0$ the distribution G is of Gumbel type, for $\xi < 0$ it is of Weibull type and for $\xi > 0$ it is of Fréchet type.

One of the theoretical premises for the application of classical extreme value statistics is that the observed events are independent identically distributed. Our time series definitely do not fulfill this assumption.

To circumvent this problem we transform the time series by extracting sequences of congested or jammed traffic and then search for a distribution governing the duration of these jams. As a jam criterion we use a velocity threshold, which may depend on the location of the vehicles on the freeway. By studying fundamental diagrams in the flow-density phase space one can find the point of maximum density in free flow and derive adaequate velocity thresholds. [2]

Our first results show that the jams are Fréchet-distributed. Ongoing work aims at validating these qualitative results.

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[1] Stuart Coles, "An Introduction to Statistical Modeling of Extreme Values", Springer (2001).

[2] Boris S. Kerner, "The physics of traffic", Springer (2004).

[3] Rolf-Dieter Reiss and Michael Thomas, "Statistical Analysis of Extreme Values", Birkhäuser (1997).