Autumn School 2016 on Algorithmic Optimization
September 19-22 at Trier University

Penalized Spline Smoothing

Speaker: Göran Kauermann (LMU München)
September 19, 2016

The lecture introduces to the basic principles of Penalized Spline smoothing as practical and numerical efficient way of smoothing. Penalized Spline smoothing has been proposed 20 years ago by Eilers & Marx (1996, Statistical Science) and became fashionable through the book of Ruppert, Wand & Carrol (2003, Semiparametric Regression, Cambridge University Press). The idea has been extended in various directions and is today's smoothing method number one. In the lecture we sketch the advantages of the approach and demonstrate how the idea of penalization can be used in various applications.

Topic List

1. Regression analysis (linear models etc)
2. Traditional smooth regression (Kernel Regression, Spline Regression)
3. Penalized spline regression (B-splines, truncated polynomials, penalization, interpolation)
4. Smoothing Parameter (AIC, cross validation, Bayesian view, Schall algorithm)
5. Spline Dimension
6. Correlated Errors and Monotone Smoothing
7. Bivariate and higher dimensional smoothing (Tensor Products, Array Formulation, Sparse grids)
8. Density Estimation
9. Quantile and expectile Smoothing (quantile sheets, expectile sheets)
10. Non-normal Data (count data, binary data)

Adaptive finite elements in numerical optimization

Speaker: Winnifried Wollner (TU Darmstadt)
September 20, 2016

This part of the autumn school will consider adaptive finite element approximations to optimization problems involving partial differential equations. To this end we will, very briefly, review adaptive finite element discretizations for the solution of partial differential equations and then discuss the state of the art of extending these techniques to optimization problems involving partial differential equations. We will place special emphasis on dual-weighted error estimates for errors in certain functionals so called quantities of interest but will also cover residual based a posteriori error estimates.

Online Optimization - Competitive Analysis and Beyond

Speaker: Sven Krumke (TU Kaiserslautern)

September 21, 2016

A situation which many of us know: You overslept, you are already late for the morning meeting, all traffic lights are on red, and once you finally reach the office building it takes ages for the elevator to arrive. Who on earth designed this elevator control system? There must be a way to craft a perfect elevator control with a little bit of mathematics! The session on "online optimization" deals with the question whether such a seemingly simple problem is really so simple.

In general, traditional optimization techniques assume complete knowledge of all data of a problem instance. However, in reality it is unlikely that all information necessary to define a problem instance is available beforehand. Decisions may have to be made before complete information is available. One classical approach to uncertain data is via stochastic optimization in which one assumes that something is known about the distribution of the input. What happens if absolutely nothing is known about the future data? The fact that in many cases the input becomes known piecewise has motivated research on *online optimization*. An algorithm is called *online* if it makes a decision (computes a partial solution) whenever a new piece of data requests an action.

The scientific challenge is: How well can an online algorithm perform? Can one guarantee solution quality, even without knowing everything in advance? This seems particularly difficult in a discrete problem where the system state can not be adopted smoothly in order to react to changing conditions. Can we still learn something from continous optimization here or is the discrete world completely different?

The session will introduce to concepts and challenges in online optimization. Online problems had been studied explicitly or implicitly during the nineteen-seventies and nineteen-eighties. However, broad systematic investigation only started when Sleator and Tarjan suggested comparing an online algorithm to an optimal offline algorithm (which has complete knowledge about the input in advance), thus laying the foundations of *competitive analysis*. The input of an online problem is given in form of a sequence $\sigma = r_1, \ldots, r_k$ which is revealed to an online algorithm piece-by-piece. An online algorithm alg for a minimization problem is called *c-competitive*, if for any input sequence σ the cost $\mathsf{alg}(\sigma)$ produced by alg satisfies

$$\mathsf{alg}(\sigma) \leq c \cdot \mathsf{opt}(\sigma) + \alpha,$$

where α is an additive constant which is independent from the input sequence.

Competitive analysis is a form of worst-case analysis and, hence, inherently pessimistic. However, a worst-case performance bound and its proof often give important insights into the structure of a problem and, finally, also helps in the construction of algorithms which are "good in practice".

In the session we will study online problems and competitive analysis for

- paging problems (caching in memory systems),
- metrical task systems (a general framework for online problems),
- scheduling problems,
- transportation problems.

We will show how to develop competitive algorithms and how to prove lower bounds on the competitiveness of algorithms. An important issue will be to study the influence of randomization: how much can an online algorithm gain by using random decisions? In addition to classical results we will cover also recent developments for the design and analysis of online algorithms.

In some cases the unrealistically strong offline adversary used in competitive analysis leads to the situation that one can prove only trivial performance bounds for algorithms (one hits the so called *triviality barrier*). In order to get criteria which algorithm to choose one needs alternative performance measures. We will study modifications of competitive analysis which restrict the "offline adversary" in her actions or the allowed input sequences. For some problems this allowes us to go beyond the triviality barrier and obtain new insights.

Multi-objective optimization

Speaker: Gabriele Eichfelder (TU Ilmenau)

September 22, 2016

In this tutorial you will get an introduction to the theoretical background and to numerical approaches for (continuous) multi-objective optimization problems. Such problems arise in almost all application areas whenever multiple objectives have to be optimized simultaneously, as for instance in portfolio optimization, engineering problems (e.g. light and stress-resistant designs), or in medicine (e.g. in intensity modulated radiation therapy). After the tutorial you will be familiar with the basic optimality notions as well as with some first characterization results for optimal solutions. These are, among others, based on scalarization approaches. Those are used for numerical algorithms for solving multi-objective optimization problems. Possible difficulties and drawbacks are pointed out. The tutorial ends with a short outlook on some of the most recent developments and research topics in this field.