Uncertainty Quantification in Gas Network Simulation

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Uncertainty Quantification

- numerical simulation: uncertainties can arise in input data or model parameters
- uncertain parameters are modeled with random variables
- **forward propagation:** how do uncertainties in the input parameters affect the quantity of interest (QoI) ?
  - specific outcome of solution
  - moments of solution (expectation, variance)
  - cdf of solution
- standard methods: stochastic Galerkin, stochastic collocation, (quasi-) Monte Carlo

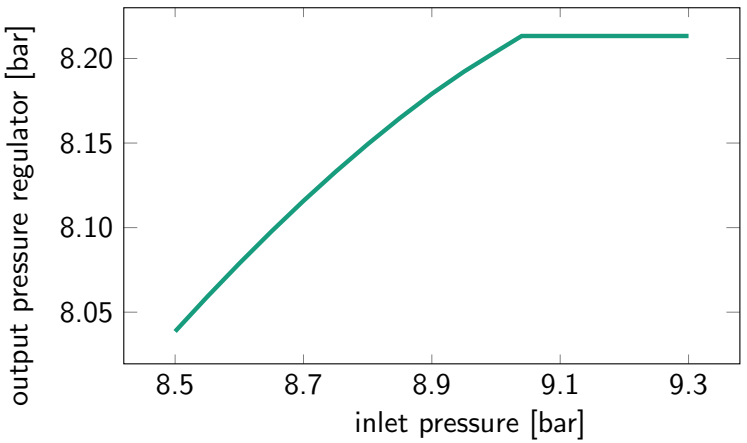
[Sullivan, 2015]

Application: Gas Networks

- scenario analyses are necessary to operate gas network safely and reliably
- scenarios are not really tested but simulated
  - multiphysical network simulator MYNTS by HPA
- uncertain input
  - how much gas does each customer withdraw?
- forward propagation
  - what happens when all customers need a lot of gas at once?
  - can the network meet all demand peaks?

Methods

- stochastic Galerkin and stochastic collation methods
  - solution must be sufficiently smooth
  - fast convergence rates
- gas networks: kinks in the solution due to pressure regulation



- (quasi-) Monte Carlo methods
  - weak requirements on solution
  - poor convergence rates

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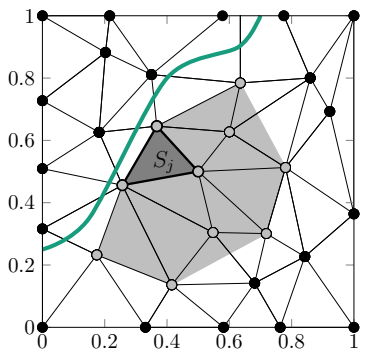
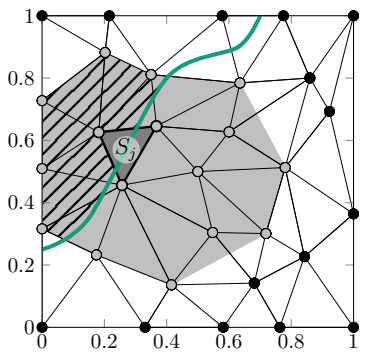
Simplex Stochastic Collocation

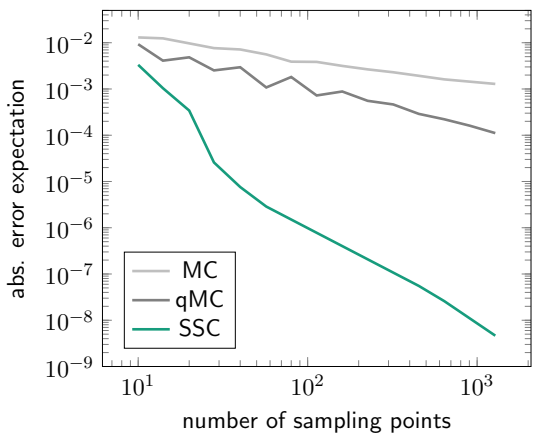
- discretize parameter space with simplices
- piecewise polynomial approximation of solution
  - Lagrange interpolation through nearest neighbors
  - exact in sampling points [Witteveen and Iaccarino, 2012a, 2012b, 2013]
- use the information whether a pressure regulator is active or not in the current simulation
  - separate approximation on each side of kink
  - at kink: minimum of both approximations



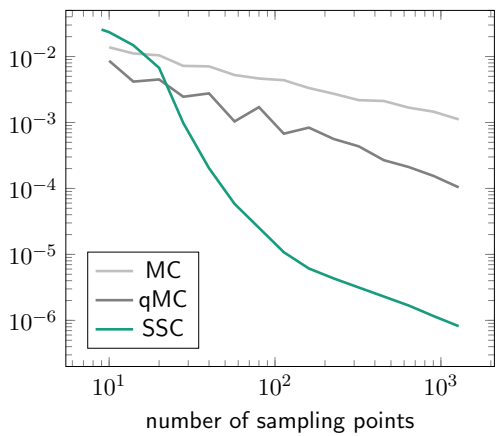


Results

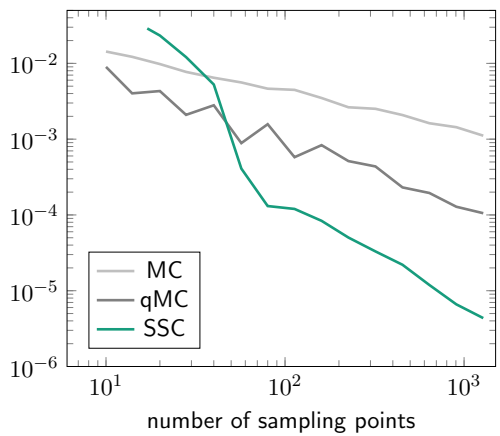
- good pre-asymptotic behavior
- model error of 10^{-4} is reached with significantly fewer sampling points
  - speed up by factor > 20 compared to qMC



(a) $d = 2$



(b) $d = 3$



(c) $d = 4$

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Thanks for your attention!