Automated Calibration for Numerical Model of Riverflow

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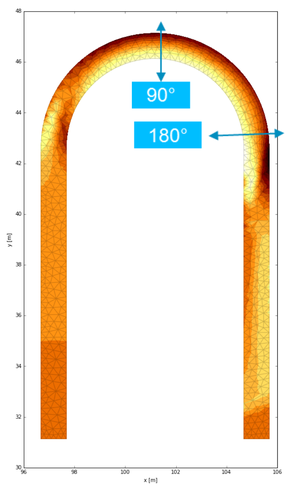
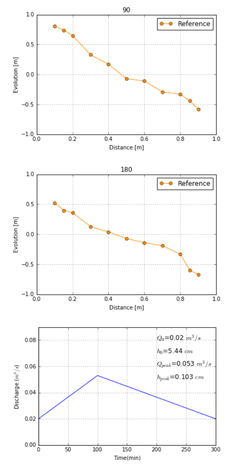
Introduction

River systems are employed in anthropogenic activities since ancient times. Therefore, it conceives the necessity to investigate their behaviors. Mathematical models are their simplified representations based on equations which contains empirical initial and local parameters that need to be calibrated. The main goals of the automated calibration are the feasibility for unexpected users and the reducing of the computer time.

Riverflow Model



The physical model consists on one-meter width flume channel with straight sections of 11.50 m long both connected by an 180° bend of 4.00 m radius. The Telemac2d-Sisyphe solvers simulate the numerical model by the hydrodynamic and the morphological governing equations which contain the parameters to be calibrated.



Automated Calibration Algorithms

Deterministic Methods

Gradient-based methods, either Newton or conjugated gradient based, rely on line search and trust region strategies; moreover, they require the Jacobian and Hessian matrix; otherwise, an approximation of first and the costly computational second derivative. Also, free gradient methods are a simple approach but commonly not self-adaptive, functions evaluations are decided geometrically.

Genetic Methods

Differential Evolution (DE) and Basin Hopping (BH) are genetic methods with some stochastic features for rejection test. In DE, Darwin biological approach is applied to reject the candidates that do not fulfill certain conditions within the population. In the BH, a perturbation is added to the parameters set; the new evaluated objective function is compared with the previous one.

Stochastic Methods

Bayes Inference Theorem with Bootstrap filter refers to information as probability distribution functions (PDF). Imperfect generated information is named Prior PDF. Real measurements constitute the conditional PDF , former and latter reduce uncertainty in the estimated parameters solutions that to construct the Posterior PDF.

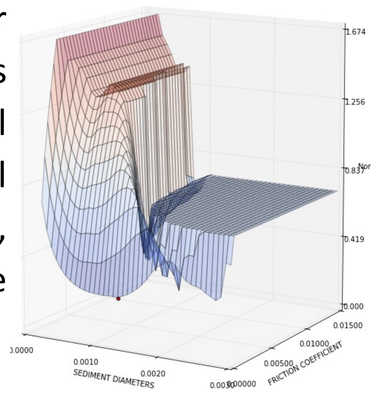
$$P(x|y_{obs}) = \frac{P(x) \cdot P(y_{obs}|x)}{P(y_{obs})}$$

Applications of Algorithms

The objective is to assess and compare the performances and efficiencies of different methods and algorithms to apply them on an automated calibration routine which simulates the numerical model as many times the method require. Those methods minimized the "Objective Function", constructed from simulated and either observed or synthetic bed evolution data.

$$\phi(\mathbf{x}^*) = 0.50\sqrt{\cdot\sum_{i=1}^{11} f_x^{90} - y_{synth}^{90}} + 0.50\sqrt{\cdot\sum_{i=1}^{11} f_x^{180} - y_{synth}^{180}}$$

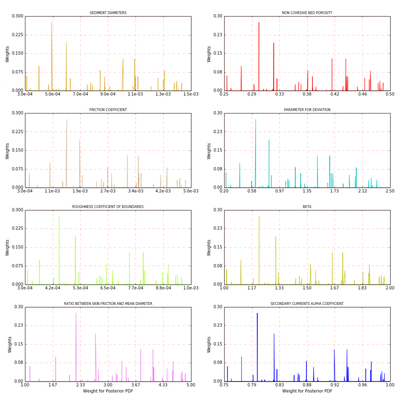
The mathematical 3D landscapes of most pair parameter combinations present non-full convexity; it implies singularities due to the channels. Unfortunately, several plateaus have been detected which stand for numerical conflicts, this is dangerous for methods based on gradients, since the derivative is zero on the plateau surface, it may be misconceived the detection of a local minimum.

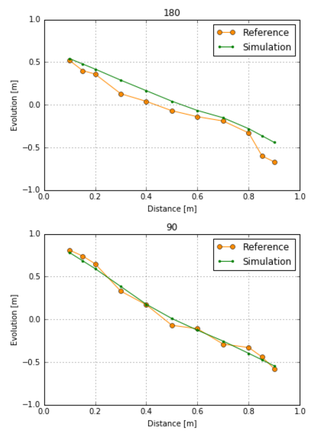


The methods assessment is based on four criteria, such as minimization of the OF, computational performance, low parameter discrepancy and constraint success. Minimization is confronted with initial function value. Computational performance condition establishes a maximal of 20 iterations and same initial parameter set. Global synthetic parameters are compared to see the discrepancies with the proposed solutions. It is observed the achievement of constraining function for the relationship of sediment diameter and roughness.

Method	C1	C2	C3	C4	Sum
Nelder Mead	10	10	10	10	40
CG	10	10	0	10	30
L-BFGS-B	10	20	0	10	40
BFGS	0	0	0	0	0
Newton CG	0	0	0	0	0
TNC	0	0	10	0	10
SLSQP	20	30	20	10	80
Trust_ncg	0	0	0	0	0
Basin Hopping	30	10	10	10	60
LeastQ	30	10	0	10	50
Root LM	30	20	0	10	60
Differential Evolution	20	10	0	0	30
Brute force	10	0	0	10	20

Prior PDF is based on the function evaluation of 1000 uniformly random parameter sets . The error of 0.0009 is used in the conditional PDF to weight the prior PDF and get the posterior PDF.





Finally, Yen and Lee model realistic measurement data are utilized as the input of the objective function, to be minimized by the most suitable deterministic and stochastic methods.

Conclusions

- An Hydrodynamic and morphodynamic model is a highly Ill-posed problem.
- SLSQP obtains the highest evaluation out of all assessed deterministic methods.
- Bayesian Inference Theory with Bootstrap filter is only suitable for a large amount of prior information.