Determination of water retention curves of rocks by a differential evolution algorithm

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Introduction

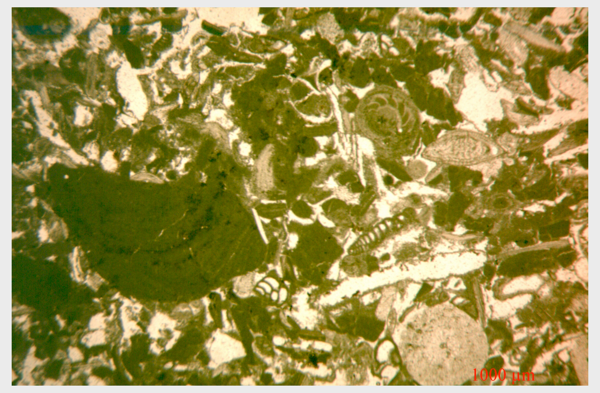
Several parametric models have been developed to describe flow and transport in unsaturated media [1-3]. The experimental data can be fitted to the models obtaining a water retention curve (WRC) which best describes the hydraulic behavior of the investigated medium.

However, all the models need a complete data set, requiring an accurate measurement of the dependence of water content, θ, on the matric potential, $-h$, using methods that are time consuming and error-prone, especially when investigating rock media [4].

Experimental

The samples belong to *Calcarenite di Gravina Formation* (Plio-Pleistocenic age), a sedimentary carbonate rock of marine origin characteristic of Apulia, southern Italy.

Calcarenite is a soft porous rock made of a granular framework of litho-bioclasts weakly cemented and soaked into a fine micritc matrix.



Optical microscope image of a thin section of Calcarenite.

A complete WRC needs at least 30 data points, distributed uniformly from full saturation to oven dryness, and up to a few months, depending on the experimental method used.

Core samples of Calcarenite di Gravina Formation.

Details on the experimental measurements and setup are presented in a companion poster (B705, Session SSS2.5/HS8.3.9).

Goal

The accurate determination of the WRCs of rocks is a complicated and time-consuming process.

How to minimize the number of experimental data points needed to model the WRCs – strongly reducing the amount of time for a hydraulic characterization of the rock samples – without sacrificing the precision of the measurement?

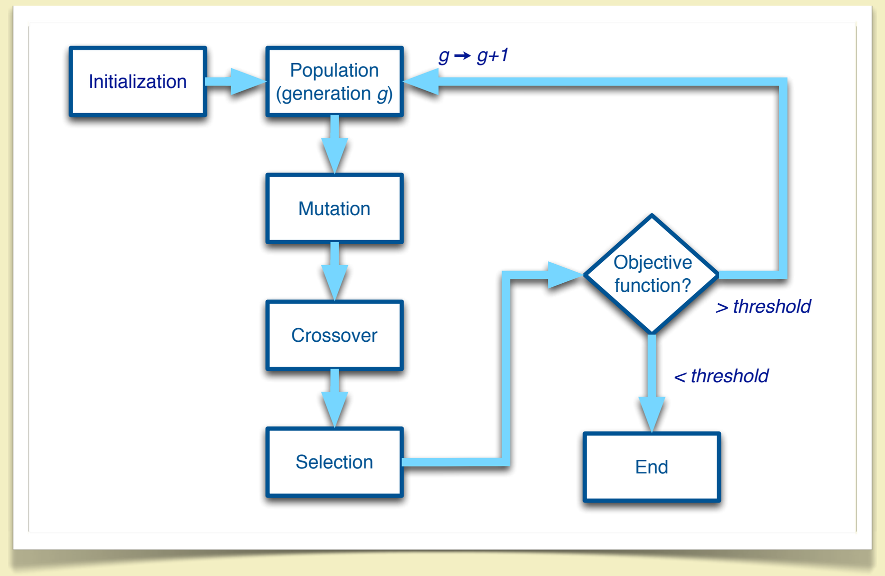
Differential evolution

New approach for the determination of the WRC of rocks.

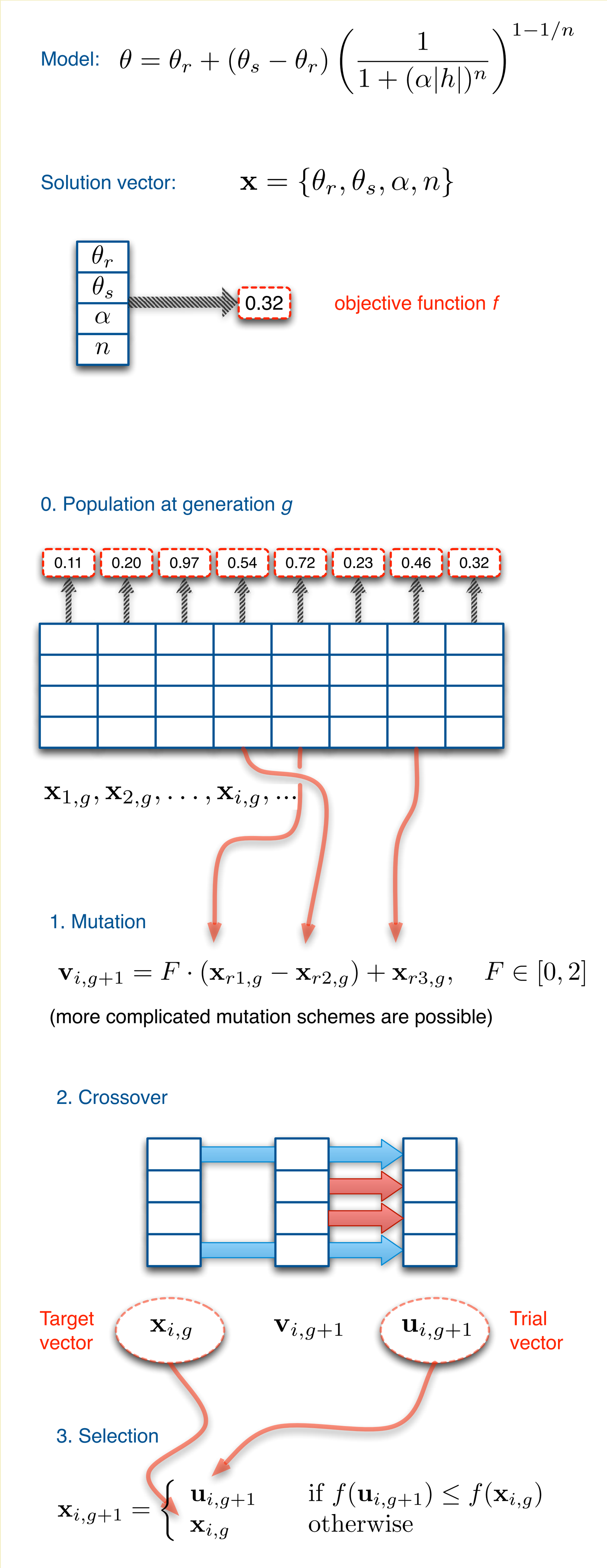
Reduce the number of measurements necessary for obtaining model parameters that accurately describe the water retention of the samples.

The method is based on the Differential Evolution algorithm (DE) [5]:

- an evolutionary stochastic global optimization method belonging to the class of genetic algorithms;
- particularly suited to optimize multidimensional real-valued functions;
- calculates the parameters that best fit the model to the available experimental data by evolving a population of solutions while minimizing the objective function of the problem;
- finds the global minimum, together with several local minima, regardless of the initial parameters.



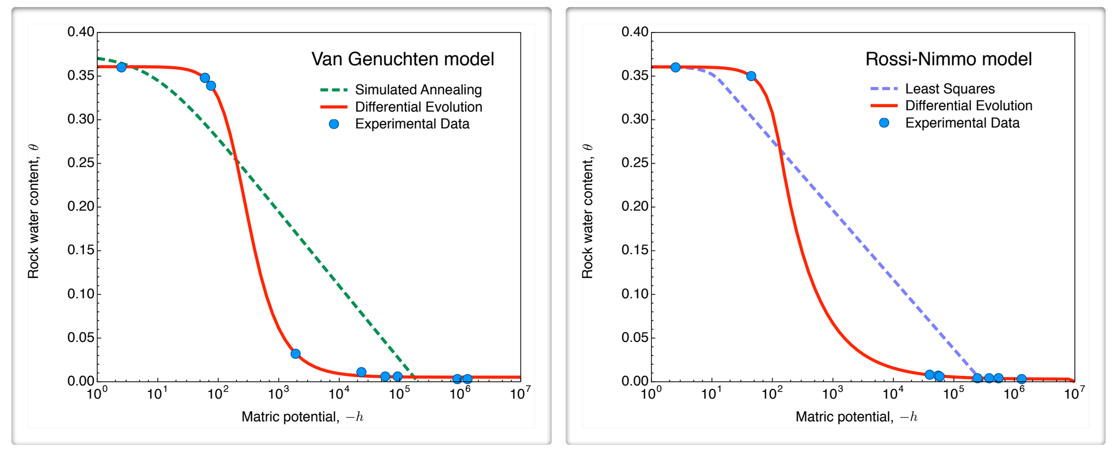
Method



Results

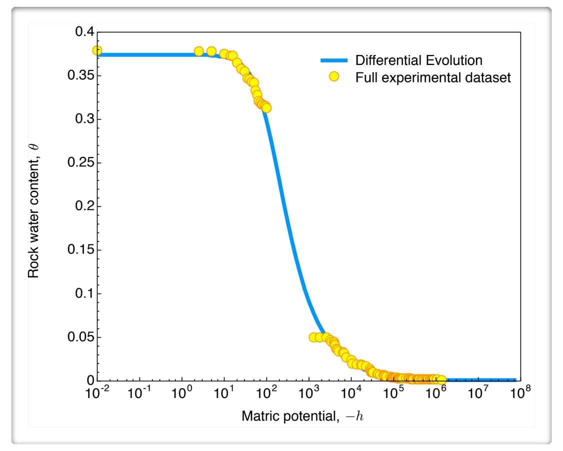
This method has been applied to several sets of measurements on Calcarenite samples. Random subsets of the measured data have been extracted to calculate the WRC parameters corresponding to the subset. The reference WRC is calculated from the complete experimental data set.

Comparison of DE with two other popular optimization methods, Simulated Annealing and Least Squares

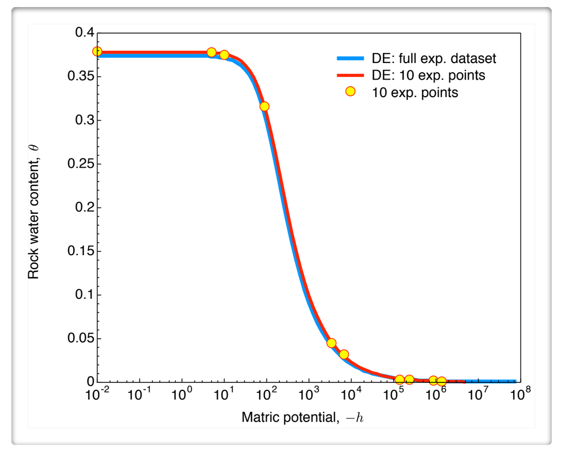


The examples above show that DE is robust and capable to find a solution – even with very few experimental points – while other methods may occasionally fail.

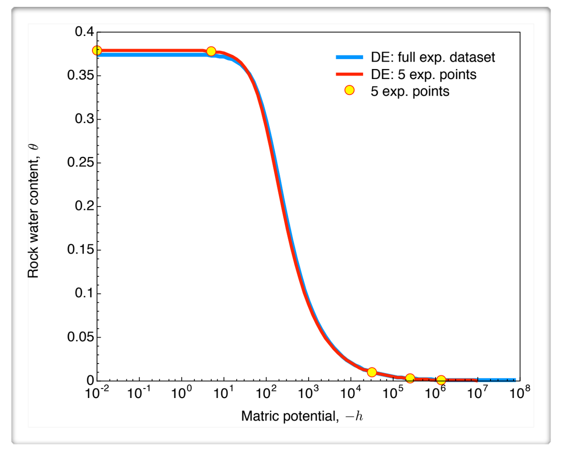
WRCs by DE from subsets of the experimental data



WRC calculated using the complete measured data set (~100 points) and the Van Genuchten model:
$\theta_s = 0.374,$
$\alpha = 8.6 \times 10^{-3},$
$n = 1.65.$

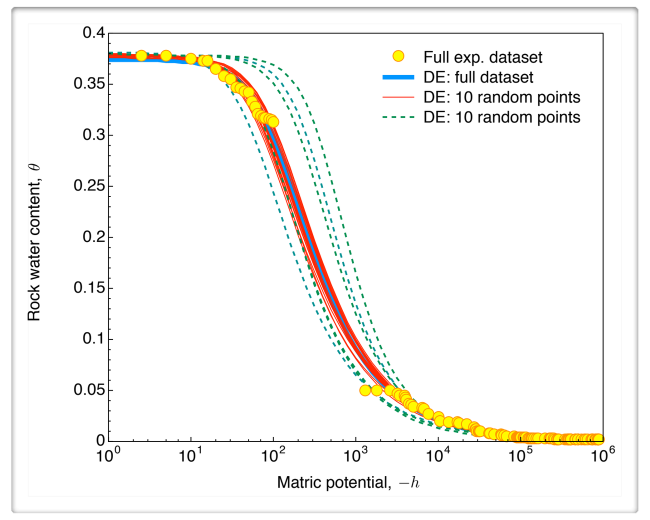


WRC calculated by selecting 10 experimental points, randomly, from the complete data set. The curve is compared to the reference WRC shown above.



WRC calculated by random selection of only 5 points from the complete data set. Even with so few points, the curve is still very close to the reference WRC.

Multiple independent runs of DE with 10 random experimental points each



The calculated WRCs in red are almost indistinguishable from the reference WRC. The few offset curves (in green) correspond to the local minima.

The average values of the model parameters, calculated using only the solutions close to the global minimum, are:

$\theta_s = 0.379 \pm 0.03, \alpha = 10.1 \pm 4.1 \times 10^{-3}, n = 1.62 \pm 0.05.$

References

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