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A discrete cellular automata approach for unsaturated flow simulation

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The parabolic partial differential equation describing fluid flow in partially saturated porous media, Richards' equation, is highly nonlinear due to pressure head dependencies in the specific soil moisture capacity and relative hydraulic conductivity terms. In order to solve Richards' equation several numerical techniques have been developed which, starting from discretization of the partial differential equation, produced more accurate models leading to complex and computationally expensive simulations for large-scale systems.

The present work describes an alternative to the classical approach, based on the assumption of the constitutive relations between dependent variable (pressure head) and nonlinear terms (moisture content, moisture capacity and conductivity), and on a preliminary reformulation of the mathematical model in a partially discrete form, which preserves the physical and geometric content of the original problem. Such a discrete approach is well suited to be implemented with cellular automata, representing systems whose global evolution may be exclusively described on the basis of local interactions of their constituent parts. Cellular automata can be easily and naturally implemented on parallel computers effectively exploiting the power of parallelism, and their elementary structure can be adapted to quantization techniques aimed at decreasing execution time, not achievable with other discrete formulations such as the cell method.

Several mono-, bi- and tri-dimensional test cases are solved, testing the reliability of the cellular automata model developed. Specifically, a bi-dimensional test-case, with highly variable hydraulic conductivity, is simulated using both the discrete approach and cellular automata as a tool to obtain a finite difference replacement of Richards'

equation, with the aim of showing the convergence between the proposed and the original approach.